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In cooperation with the University of Minnesota Agricultural Experiment Station

SOIL SURVEY
OF
WADENA COUNTY, MINNESOTA

BY

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COUNTY SURVEYED

Wadena County is a little north and west of the geographical center of Minnesota. It is rectangular in outline, the dimensions being about 30 miles north and south and 18 miles east and west. The land area is 535 square miles or 342,400 acres.

In its physiographic relations Wadena County is in the region of the young glaciated plains of the north-central United States. Its features of relief are determined largely by the deposition of the glacial drift, as very little change in form has been produced by subsequent dissection. There are no decidedly conspicuous topographic features, but the surface is not without variety. Two fairly distinct kinds of relief may be distinguished and correlated with recognized glacial forms. About one-third of the county consists of gently rolling or undulating uplands, composed of glacial till deposits, between which are depressions containing peat bogs. The remainder of the county consists of nearly flat or undulating sand plains broken by shallow broad or linear depressions filled with peat.

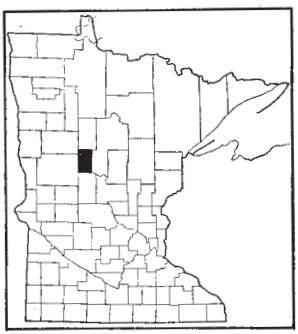

FIGURE 1.—Sketch map showing location of Wadena County, Minn.

The largest and most conspicuous of the rolling uplands lies between Leaf and Redeye Rivers and extends northward into Red Eye Township and the western and southern tiers of sections in Blueberry Township. Another area, less rolling but noticeably undulating as compared to the more level adjacent lands, occurs in Orton and northern Lyons Townships. A distinct ridging, with the prevailing axes of the ridges northeast-southwest, is a distinctive feature of most of these rolling areas. Over these rolling tracts of land the individual slopes are generally gentle, except in places along some of the streams.

The other type of relief, that of an almost level or very gently undulating plain, prevails over the remainder of the county. Over these lands the only variations from the characteristic topography are scattered ridges of glacial till, flat depressions filled with peat or shallow water, rather abrupt rolling slopes to the river valleys, and more undulating sections of the lake region in Blueberry Township and eastward along Shell River. The stream bottoms are gen-

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erally narrow and irregular, averaging one-fourth mile in width. The widest stretch of bottom land, ranging from one-half mile to 2 miles in width, is along Leaf River in Leaf River Township. In many places the streams flow through a series of connected constructional depressions rather than through a true stream valley carved by the flowing water. From the valleys the elevation of the surrounding plain is attained in most places by a single slope without intervening stream terraces, although south of Leaf River there are some lower terraces, fairly distinct and of fair size. These lower terraces elsewhere in the county are fragmentary and very narrow. The larger stream bottoms lie from about 25 to 50 feet below the adjoining upland.

The highest land is in the northwestern part of the county, where the elevation is about 1,400 feet above sea level,[1] and the lowest point, which is 1,225 feet above sea level, is in the bed of Crow Wing River at the east county line. The mean elevation for the county is about 1,350 feet.

Wadena County in its native state was largely timbered. Much of the land south of Leaf River has a surface soil which indicates an original grass vegetation, but descriptive notes, such as "oak openings, hazel brush, or jack pine," appearing in survey records of the General Land Office, as well as small remaining patches of small timber and brush, show that this section was not entirely an open prairie. The heavier soils of the rolling uplands supported a dense stand of mixed conifers and hardwoods, in which white pine was prominent. On the dry sand plains, jack pine was the characteristic and in places the exclusive tree growth. The peat bogs were partly open grassland and partly timbered with tamarack, spruce, and cedar, with some swamp hardwoods. Large clearings have been made in the timbered lands. Bullard Township, with only one-eighth, and Huntersville Township, with only one-sixth, of the land in farms, have the largest acreages of timbered or recently cut-over lands. About two-thirds of Lyons and Shell River Townships and one-half of Blueberry, Orton, Meadow, North Germany, and Red Eye Townships remain timbered or in brush. The present cover differs greatly from the original. On the heavier soils of Leaf River, Rockwood, Red Eye, and parts of Blueberry Townships there is mixed small timber and brush in which aspen, locally called popple, predominates, together with scattered white and red (Norway) pines, balsam fir, white spruce, balsam poplar, boxelder, red oak, northern bur oak, elm, canoe birch, ironwood, black and green ash, wild plum, and wild cherry.

Wadena County lies entirely in the watershed of Crow Wing River, an important tributary of Mississippi River. The tributary stream development is apparently erratic and immature, being largely determined by the deposition of the glacial drift. However, for the most part the main streams of the county have a rather rapid rate of flow. In the tributary drainage the flow is sluggish as the headwaters are approached and most of the streams are lost in peat bogs. In many places ditches have provided better discharge of water from chains of peat bogs to the natural drainage courses, and waters from many

[1] UPHAM, W. GEOLOGY OF WADENA AND TODD COUNTIES. Minn. Geol. and Nat. Hist. Survey Rpt. (1882–1885) 2: pp. 562–579, illus. 1888.

of the more meandering sluggish streams have been diverted into straighter ditched courses.

There are about 250 linear miles of drainage ditches in the county, the smaller of which are not maintained in the best operating condition. The drainage and utilization of poorly drained lands are most advanced in Aldrich and Leaf River Townships. Drainage ditches in operation in Huntersville, Orton, Lyons, and Meadow Townships are almost as extensive as in Leaf River and Aldrich Townships, but the lands have not as yet been so thoroughly benefited and utilized. The largest acreage of undrained land is in eastern Meadow and northwestern Bullard Townships. Wadena, Blueberry, and Thomastown Townships have the smallest acreages of poorly drained land.

Lakes are comparatively few and small. They occur in the northern part of the county and along Crow Wing River in the eastern part. Many of the smaller lakes are partly drained and very shallow, with aquatic vegetation appearing on the surface.

Although the drainage systems of Wadena County do not have a regular and frequent interval of tributary development, affording drainage by that means, the lands of the interstream areas, except for the peat bogs and lowland depressions, are generally well drained by virtue of a porous gravelly or sandy substratum or because of good surface run-off afforded by the original relief of glacial construction.

The county is traversed by lines of two railways, the Northern Pacific and the Great Northern. Paralleling the railroads are graveled highways which are a part of the State and national highway systems. There were, in 1926, 55 miles of such mainland gravel roads and 160 miles of county maintained dirt roads. Trails or secondary roads still bear much of the travel in Orton, North Germany, eastern Meadow, and northern Lyons Townships, but they are being replaced by new public highways. Only a comparatively small acreage of land remains inaccessible by roads.

Rural mail and telephone services reach all parts of the county and rural and consolidated schools provide good school facilities.

There are seven shipping points along the railroads in the county. Five inland trading centers provide their communities with poultry and dairy produce markets. The grain and livestock shipped from the county are consigned mainly to Minneapolis and South St. Paul, and small quantities are sent to Duluth.

The 1920 population of Wadena County was 10,699, all classed as rural. The southern part of the county was the first to be settled, then the western part, then the north and east parts, which are still rather sparsely settled. Many of the early settlers were of foreign birth. A State census of 1895 showed about one-third of the population of the county to be foreign born. The foreign-born population in 1905 constituted about one-fifth of the population.

Wadena County was organized from a part of Cass County. Between 1870 and 1875 the extension of the Northern Pacific Railway from St. Cloud to Moorhead gave the county its first railroad. All vacant public lands in the southern part of the county soon passed into private ownership, and lands granted the railroads as quickly became private property. A good start in the agricultural settle-

ment of this section had been made by 1880, when the supply of timber became exhausted and lumbering activities declined. Settlement grew from 1880 to 1900. The Federal censuses show that the acreage in farms increased from 11.2 per cent of the county acreage in 1880 to 41.1 per cent in 1900. The greater expansion occurred in the nineties. From 1900 to the present the expansion of farm acreage has been less and less, as settlement covered the greater part of the better agricultural lands of the county.

CLIMATE

The climate of Wadena County is temperate and is characterized by short but warm summers and long cold winters. Temperature conditions are most changeable during fall and spring.

The average length of the frost-free season is 127 days, the latest frost occurring on May 16 and the earliest on September 20. The latest and earliest killing frosts recorded, respectively, were on June 6 and August 25. Moderate temperatures with moist soil conditions brought about by thawing of the winter snows and the moderate rainfall of the months of March and April help to make conditions desirable for planting small grains during April and potatoes in May. A warmer condition of the ground is required for planting corn and flax. The distinctly higher temperatures of the latter part of April and May usually make these plantings safe after about May 10 or May 20. In June increasing temperatures and rainfall contribute to a rapid growth of small grain and hay crops and to a good germination and stand of corn. It is in the warmer month of July that corn makes the greatest stalk growth. The ripening, maturing, and harvesting season for small grains is from the last of July to the middle of August. As a rule, weather conditions are favorable, but variations in temperature greatly affect the yield in some seasons. Dry weather occurring just before the ripening stage causes a poor fill and shriveled grain. Excessive rains postpone ripening and, if they continue during harvest, make proper curing of the grain difficult. Unusually warm and moist weather in May is favorable to corn. The rainfall gradually decreases through July, August, and September, and, although it is usually well distributed, there are many seasons in which dry spells damage crops on the poorer sandy soils. As a rule, warm weather favorable for the maturing of crops, for fall plowing, and for seeding rye continues well into September. October and November are characterized by rather dry, open weather, with warm days and frosty nights. Short cold spells with light snowfall occur with slightly increasing frequency and duration as the season advances toward winter. Usually by the last of November the ground is frozen. Extremely cold weather with temperatures below zero last as a rule for only short periods; thawing temperatures also are of only short duration during the winter. Snow provides a protecting blanket for meadows and fall-seeded crops during most of the winter and is a valuable and much-needed source of moisture for spring plantings.

Damaging windstorms or hailstorms are of very occasional occurrence on small localized spots or strips of land.

Table 1, compiled from records of the Weather Bureau station at Park Rapids, about 10 miles north of the county, shows the normal monthly, seasonal, and annual temperature and precipitation of the region in which Wadena County occurs.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Park Rapids, Hubbard County*

[Elevation, 1,426 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1910)	Total amount for the wettest year (1899)	Snow, average depth
	°F.	°F.	°F.	Inches	Inches	Inches	Inches
December	11.6	54	−44	0.70	0.65	0.31	6.5
January	2.4	51	−47	.76	.60	.63	7.0
February	5.7	52	−51	.61	.47	.28	6.0
Winter	6.6	54	−51	2.07	1.72	1.22	19.5
March	21.9	80	−38	1.04	.18	.91	7.6
April	40.4	87	−8	2.17	2.79	2.35	5.5
May	52.4	92	17	3.15	.75	7.99	.8
Spring	38.2	92	−38	6.36	3.72	11.25	13.9
June	62.8	101	27	4.23	.70	9.06	0
July	67.7	104	38	3.99	1.59	3.42	0
August	64.2	98	28	3.64	.68	8.59	0
Summer	64.9	104	27	11.86	2.97	21.07	0
September	55.4	96	18	2.41	3.21	1.73	.1
October	42.7	87	−3	1.97	1.93	2.78	1.9
November	26.5	67	−32	.92	.80	.52	6.2
Fall	41.5	96	−32	5.30	5.94	5.03	8.2
Year	37.8	104	−51	25.59	14.35	38.57	41.6

AGRICULTURE

At present, farming in Wadena County is of a rather diversified type in which dairying is the chief livestock industry and corn and oats are the main cultivated crops. In general the acreages of wild hay on the farms are larger than of tame hay. Even on Rockwood loam, where larger acreages of tame hay are grown, the acreage of poorly drained soils in wild hay is larger. Many of the farmers in the northwestern part of the county and on similar sandy soils elsewhere, because of the poorer adaptation of these lands to tame hay, depend almost entirely on the wild-grass meadows on peat and other poorly drained lands for their hay supply. On many of these farms the poorly drained wild-hay meadows are of larger total acreage than the cultivated lands.

From three-fifths to four-fifths of the acreage of the farms on the prairies (Wadena soils) of the southern part of the county are in cultivated crops. Between a fourth and a third of the farm acreage is in cultivated crops on the Rockwood soils. The farms on the sandy Menahga soils have only about one-fifth and those on the Kinghurst soils about one-sixth of the farm acreage in cultivated

crops. Crops grown are different on the farms of these four groups. On the prairie farms a much greater acreage than elsewhere is in corn and oats and other small grains. The acreage of tame hay (principally clover and timothy) is greatest on the farms on the Rockwood soils, comprising about one-tenth of their acreage, whereas about one-fifteenth of the prairie farm acreage and only 3 or 4 per cent of the farm acreage on the Kinghurst and Menahga soils are in these crops. Alfalfa is well established and is increasing in acreage on the farms on the prairie soils. The acreage on the farms on the Rockwood soils indicates a fair start in alfalfa growing. The farms on the Menahga soils, however, have but small, scattered, thin stands.

Activity in the livestock industries differs to some extent on the farms of these four groups. Cattle are kept in greater numbers than any other livestock on all the farms. The numbers kept on farms on the prairie and sandy soils average about the same, but those kept on the prairie areas of Wadena soils are better bred and receive better care. A few more cattle are kept on the farms of the Rockwood soils than elsewhere, and the quality of the stock and care given them are almost as good as in the prairie section. Sheep are also kept in slightly greater numbers on these farms, the numbers kept on farms on the Wadena and Kinghurst soils averaging about the same and on the Menahga soils being very small. Farmers on the Wadena soils give much attention to hog raising, whereas on other farms of the county, particularly in the sandy sections, this industry is unimportant.

Table 2 gives a fairly concrete idea of the average type of farming in the county.[2]

TABLE 2.—*Acreage, production, and acre yield of principal crops in Wadena County in 1924*

Crop	Acreage	Production	Acre yield	Crop	Acreage	Production	Acre yield
		Bushels	*Bushels*			*Tons*	*Tons*
Oats for grain	20,448	596,917	29.2	Hay	32,174	33,271	1.0
Corn for grain	2,458	49,036	19.9	Wild hay	16,909	----	----
Rye	4,364	68,997	15.8	Clover and timothy mixed	4,666	----	----
Barley	2,552	67,298	26.4	Clover alone	4,399	----	----
Wheat	1,975	34,348	17.4	Timothy	461	----	----
Flax	707	5,611	7.9	Alfalfa	1,515	----	----
Buckwheat	145	1,314	9.1	Small grains cut for hay	212	----	----
Sweet corn	788	----	----	Annual legumes cut for hay	24	----	----
Potatoes	3,189	308,284	96.7	Other tame grasses	3,988	----	----
Dry edible beans	138	----	----				

The census shows a steady increase in the corn acreage. A little more than half the acreage planted is usually matured for grain, which is practically all used locally. About one-third of the corn is cut for fodder in normal seasons, and in shorter growing seasons half or more than half is used in this way. Home-grown mixed seed is usually planted. Of the pure strains sown, the most popular are Minnesota 13, Minnesota 23, Rustler White Dent, Northwestern

[2] Unless otherwise stated, figures quoted in this report are taken from the Federal census.

Dent, and Pearl Flint. The last-named variety is planted for forage and hogging down. A few farmers produce seed corn on a small scale, mainly under contract to seed houses.

The census shows a steady increase in the acreage of oats. Home-grown seed of mixed varieties is most commonly sown. The most popular varieties are Swedish Select, Silvermine, Big Four, and Gopher, all of which are early or medium early maturing varieties. Practically all the oats produced are used locally for feed.

A marked decline in the acreage of rye occurred between 1919 and 1924. At present the greater part of the crop is utilized locally for feed. Home-grown seed is used. A small acreage is fall pastured and plowed under in the spring as a green-manure crop. A pure strain variety of spring rye, Swedish (Minnesota No. 2), recently has been grown to some extent.

The barley acreage has increased slowly and steadily in the 15-year period 1910 to 1925. Most of the crop is used locally for feed, but very small surpluses are shipped. Mixed home-grown seed is used. Of the pure strains, the Manchuria, Oderbrucker, and Velvet varieties are most popular.

The potato acreage differs from year to year, with the advance and decline of prices. In 1922 and 1923 the acreage was two or three times as great as at present (1926). The popular varieties grown are Early Ohio, Triumph (Bliss Triumph), Green Mountain, Rural New Yorker, Irish Cobbler, and Burbank Seedling (Burbank).

The wheat acreage of the years 1922 to 1924 ranged from 1,000 to 2,000 acres, a considerable decrease from the 5,817 acres reported in 1919 and the 25,657 acres in 1900. Low market prices and declining yields seem responsible for this decrease. The crop is largely used as feed, with small surpluses marketed. Almost the entire acreage is spring wheat. Home-grown seed is used by most farmers. The most popular varieties are Marquis and Bluestem, and a considerable acreage of durum wheat, used for making macaroni, is grown for market.

The high market prices of 1920 and the few following years were responsible for a steady increase in the flax acreage. The 1924 acreage, although small, was double that reported for 1919. Flax is entirely a cash crop. Common home-grown seed is mostly used. Of the pure strains, the wilt-resistant varieties such as North Dakota Resistant Nos. 114 and 152, Winona, and Chippewa are the most popular.

Wild hay constitutes a little more than half the hay crop of the county, but since 1900 the acreage of the higher quality tame hay has increased greatly. During the period 1919 to 1924 the census shows a marked decline in the acreage of timothy alone and a corresponding increase in the acreage of red clover; the acreage of timothy and clover mixed remained about the same. Alfalfa increased greatly in acreage in that period and sweetclover and soybeans appeared as additional cultivated hay crops. White biennial sweetclover and Grimm and common strains of alfalfa are grown. Medium red clover is most popular, but some mammoth red clover and alsike clover are seen. Most of the tame grasses are mown for hay, a small acreage is used as green forage, and a still smaller acreage is harvested for seed. Crops on the sandier soils are the most consistent seed producers, but are not so high yielding as crops on the heavier

soils in favorable seasons. Most of the hay crop is fed in the county.

Other crops of very minor acreage are rape, rutabagas, carrots, mangels, sugar beets, buckwheat, millet, emmer, spelt, field beans, and onions. Within a radius of about 10 or 15 miles of the canning factory at Wadena a considerable income is derived from the production of canning crops such as sweet corn, cucumbers, peas, and cabbage.

Fruit raising is given little attention as a rule. Very small acreages of strawberries, raspberries, and blackberries are grown and marketed locally. Among the orchard fruits plums rank first. The recent introduction of new varieties has caused an increase in plantings. Cherries rank second in number of trees, followed by apples.

In the cultivation of crops the principal weeds to combat are quack grass, sow thistle, Canada thistle, and foxtail. Other common weeds which occur, but not as serious pests, are mustard, wild morning-glory, ragweed, smartweed, cockleburs, French weed, and Russian thistle. Damage from insects and disease is severe only locally during occasional seasons. The principal insects to combat are the potato beetle, the grubworm, wireworm, cutworm (usually troublesome only on newly broken sod land), aphids on field crops (mainly small grains), and the plum curculio. The principal diseases are scab, wilt, and Rhizoctonia of potatoes, rusts and smuts of small grain, mildew of clover, and wilt of flax. Corn is fairly disease free, the most common disease being smut, which seldom if ever causes much damage.

In 1925 there were in the county 4,431 horses, 83 mules, and 16,593 cattle. Of the total number of cattle reported, 835 were beef cows 2 years old or older and 9,787 were dairy cows 2 years old or older. The total number of hogs in the county was 8,252 and of sheep, 2,922. The livestock is mainly grade stock of good quality. Only a very few entire herds of purebred cattle are kept. The interest in good breeding is greater in connection with cattle than with other livestock. Among the sheep and hogs the number of purebreds is not so great. The Holstein is the most popular breed of cattle at present, with milking Shorthorn, Guernsey, and Jersey next in order of rank. The popular breeds of hogs are Duroc-Jersey, Poland China, Chester White, and Hampshire. By far the greater percentage of purebred sheep are Shropshires, but Lincoln and Hampshire are represented. The work animals consist largely of horses of a good draft type.

Fair or good grades of poultry are kept by most farmers. Of the pure strains of chickens the most common are White Leghorn, Barred and White Plymouth Rock, Buff Orpington, Rhode Island Red, and Ancona. Turkeys, geese, and ducks are kept in much smaller numbers.

Slight interest is shown in honey production, the 1922 Minnesota State farm census reporting 261 stands of bees kept.

In 1924 the value of livestock in the county was as follows: Cattle, $712,734; horses and mules, $335,965; hogs, $112,329; sheep and goats, $30,444; and poultry, $71,978. The total value was $1,263,450. Dairy products were valued at $519,667; poultry and

eggs at $159,157; and wool at $5,792. The total value of livestock products is placed at $684,616. In the same year the value of all crops was $947,884.

The 1925 census reports the average value of farms in the county as $8,023, of which 59.8 per cent is in land, 23.5 per cent in buildings, 12.1 per cent in livestock, and 4.6 per cent in implements. The farms of the prairie soil section are the best improved and best equipped. The farms of the Rockwood soil section rank next in buildings and equipment, and those on the sandy Menahga and Kinghurst soils rank lowest, though the established and more prosperous farmers in these sections have well-improved farms.

The only fertilizer used on the average farm is manure produced on the farm. The manure is most commonly applied to hay meadows or small-grain stubble before plowing for a cultivated crop such as corn or potatoes or is applied as a top-dressing for pastures and meadows. Commercial fertilizers are used only on small acreages of truck and special crops. Some liming is done on alfalfa ground.

Practically all the labor is done by the farm family, with some exchange of labor among groups of farmers. Hired labor is practically all local and is employed during the busiest times of harvest and haying. Summer wages range from $45 to $60 a month.

In 1925, 19.6 per cent of the farms in the county were operated by tenants. This indicates a slow increase in tenancy, as compared with the 9.8 per cent reported in 1900. The prevailing form of tenancy is under a share rental contract of from one to five years. The shares fixed differ with the proportion of equipment and livestock furnished by each party. Pasture lands are most commonly rented for cash, prices at present ranging from 50 cents to $1.50 an acre.

In 1925 the average size of the farms in the county was 150.2 acres. The value of the land was reported as $31.97 an acre.

SOILS

There are two rather distinct groups of well-drained soils in Wadena County, as follows: (1) Very dark-colored soils, which may be called the Wadena group; and (2) light-colored soils, which may be called the Rockwood-Menahga group. These two groups of soils, although they grade into each other, are in general geographically separate. The dark-colored soils occur in the southern part of the county and as a very narrow fringe which extends southward from Hubbard County into the northern edge of Wadena County. The light-colored soils, with a group of intermediate soils subsequently described, occupy the remainder of the well-drained lands of the county. The correlation of these two groups of soils with two distinct kinds of vegetation is well recognized and known to the farmers of the region. The dark-colored soils had a cover of grass with only scattered trees and the light-colored soils had a dense timber cover. In the first group the surface soils are darkened, to a depth ranging from 12 to 18 inches, by the organic matter of decayed grass roots, mixed with the mineral constituents of the soil; in the second group there is little darkening of the surface soils from organic material.

Intermediate between these two groups of soils is a group of well-drained soils in which incorporation of organic matter in the surface

soil has proceeded to the extent of producing a slightly darkened color or only a thin layer of a distinctly dark cast on the surface. In this group are the Nymore, Central, Marquette, and Thomastown soils.

The poorly drained areas of the county, confined for the most part to distinct depressions, are largely covered with deposits of organic matter constituting peat and muck. Poorly drained mineral soils, which have been classified in the Sebeka, Granby, Newton, and Bluffton series, occupy a total of about 50 square miles in the county.

On the basis of subsoil characteristics the soils may be divided into two groups, one group having friable uniformly oxidized subsoils and the other poorly oxidized mottled somewhat plastic subsoils in the heavier-textured soils and rather friable but compacted subsoils in the lighter sandier soils. Marked differences in prevailing drainage conditions account for these differences. The uniformly oxidized friable subsoil has been and is well drained and well aerated. Certain soils having such subsoils have been excessively drained, giving ample opportunity for the deep leaching of soluble chemical constituents, such as lime carbonate, and for the transporting of the small percentage of fine soil particles originally present from the surface soil to a considerable depth. The result has been loose porous sandy surface soils and subsoils leached of lime and showing an acid reaction to a depth of 5 or more feet. Such conditions exist in the Menahga, Nymore, Aldrich, and Kinghurst soils.

Other well-drained soils have not been so deeply leached and the soil is not so strongly acid to as great depth. The finer soil particles are commonly concentrated near the surface in a heavier-textured underlayer ranging in thickness from 6 to 16 inches. One series, the Wadena, comprises soils of this character. Two other series, the Hubbard and Central, are closely allied to the Wadena, but in them the lime carbonates have been leached to a depth of 4 or 5 feet. Soils of still another series, the Marquette, resemble the Wadena except in their much thinner layer of fine-textured soil particles. The Thomastown soils are not so advanced in weathering as the Wadena and exhibit no marked translocation of fine soil particles or soluble chemical constituents, but because of their appearance of good oxidation they belong to this group more nearly than to any other.

The other well-drained soils of the county are grouped in the Rockwood series. A profile of the soils of that series shows a thin layer of gray soil, a grayish-brown layer, a dark-brown slightly heavier-textured layer, and a moderately well-oxidized heavy-textured substratum in which lime carbonate has been leached to a depth of 5 or 6 feet. The gray layer is one in which there is very little organic matter and from which the basic elements and coloring from red iron oxide have been more completely leached than from the soil layers below. This gray layer, which is commonly only an inch or two thick, is not found in any of the other light-colored soils of the county.

In the group of poorly drained and poorly oxidized soils are the Newton, Sebeka, Granby, and Bluffton soils. The Bluffton soils, by reason of being the heaviest textured of the group, show the most poorly oxidized and least altered condition. Internal drainage as well

as surface drainage has been restricted, and the result is a soil unleached of its lime carbonate even at the surface in places. In the Granby soils the lime carbonate appears on the average at a depth of 2 or 3 feet. In the Newton and Sebeka soils the lime carbonate lies deep, and the acidity is medium or strong. In the Newton and over considerable areas of the Sebeka soils a thin surface covering of peat or muck is characteristic. Only in the Newton soils has there been a darkening of the surface soil directly beneath this layer. It may be that such an organic-matter covering once existed on the Bluffton and Granby soils. The only evidence at present is the slightly mucky consistence of the surface layer where drainage conditions are the poorest. If such a layer existed its identity at the present time has largely been lost, and it has become a part of the black surface soils of high organic-matter content.

Over a considerable acreage in the county where drainage conditions have been most restricted and have effected conditions of swampiness, there is a thick layer of peat or muck. An abundant growth of water-loving grasses, sedges, mosses, and other plants, and of tamarack, black spruce, and some cedar or arborvitae contributed to the accretion of this layer. These peat coverings range from 1 to 15 or more feet in thickness. In the shallower areas the slightly altered soil material is beneath the peat and almost directly beneath this is the unaltered parent soil material. Just as in the well-drained soil areas this substratum is predominately sandy. The areas of muck show this organic accumulation in a more advanced stage of decomposition and intermixed with greater proportions of mineral soil particles than in the areas of peat. In their present state of drainage the muck areas are similar to the peat areas, but are not quite so wet. In few places is the thickness of the muck more than 3 feet; it averages about 1 foot.

The geologic substratum below the soils of Wadena County is glacial drift of Wisconsin age. This material is partly an unconsolidated mass of clay, sand, and gravel, dominantly gray in color and of moderate lime content, and partly assorted water-laid sand and gravel. Certain characteristics, especially of texture, of the mineral soils of the county show the relation of the soils to the geologic strata. Thus, from the unconsolidated glacial till are derived the Rockwood and Bluffton soils and from deposits of sandier, coarser material, which may be in part ice-laid till and in part water-laid deposits, the Kinghurst and Marquette soils. From the sandier water-laid strata are derived the Menahga, Nymore, Aldrich, Sebeka, and Newton soils, and from the more gravelly or in places more clayey assorted drift deposits are derived the Wadena, Hubbard, Central, and Granby soils.

Most recent in geologic age are the alluvial flood plains of the county. Weathering agencies have effected fewer changes on these deposits than on the older glacial till and water-laid outwash plain deposits. The undifferentiated alluvial soils, the Griffin soils, and certain areas of the Thomastown soils are derived from such deposits.

Peat and muck occur wherever the local conditions have been favorable for the formation of organic deposits, entirely irrespective of the character of the geologic substrata.

On the basis of essential differences in their physical characteristics and, as far as can be determined by field inspection and present knowledge concerning their chemical characteristics, the soils of the county are classed in series. In turn, these series are subdivided into soil types on the basis of the texture of the upper soil layers. In this county 15 series of mineral soils, which include types ranging in texture from sand to silty clay, are represented. In addition, two types of peat, each with a shallow phase, muck, and alluvial soils (undifferentiated) are separated on the soil map and described in the report.

In the following pages the various soils of the county are described. Table 3 gives the acreage and proportionate extent of each soil.

TABLE 3.—*Acreage and proportionate extent of the soils mapped in Wadena County, Minn.*

Type of soil	Acres	Per cent	Type of soil	Acres	Per cent
Rockwood loam	38,080	11.7	Sebeka sandy loam	1,088	0.3
Poorly drained phase	2,176		Bluffton silty clay	5,504	1.6
Rockwood sandy loam	15,296	4.5	Bluffton sandy loam	1,088	.3
Rockwood loamy sand	3,968	1.2	Granby clay loam	2,624	.8
Kinghurst loamy sand	12,928	3.8	Granby sandy loam	5,184	1.5
Aldrich loamy sand	3,200	.9	Newton sand	4,352	1.3
Wadena sandy loam	38,016	11.1	Newton sandy loam	1,728	.5
Wadena loamy sand	8,960	2.6	Thomastown loamy sand	2,240	.7
Wadena loamy fine sand	384	.1	Thomastown fine sandy loam	1,472	.4
Wadena loam	4,352	1.3	Griffin silty clay loam	320	.1
Central loamy sand	3,968	1.2	Alluvial soils (undifferentiated)	9,024	2.6
Central sandy loam	896	.3	Badoura peat	33,280	13.5
Hubbard sandy loam	640	.2	Shallow phase	13,120	
Nymore loamy sand	11,136	3.2	Rifle peat	25,920	7.8
Menahga loamy sand	55,680	16.3	Shallow phase	704	
Menahga sand	15,616	4.6	Muck	5,120	1.5
Menahga loamy fine sand	1,088	.3			
Marquette sandy loam	832	.2	Total	342,400	
Sebeka loamy sand	12,416	3.6			

ROCKWOOD LOAM

Rockwood loam has about a 2-inch covering of leaf mold and other organic matter, underlain by about a 1-inch layer of fine sandy loam or very fine sandy loam, distinctly gray, mellow, structureless, and single grained when dry and very dark grayish brown, friable, and showing practically no stickiness when wet. This is underlain by about an 11-inch layer of single-grained or very finely granular loam or heavy fine sandy loam, light yellowish gray and friable when dry and grayish brown, coherent, and very slightly sticky when wet. The next lower layer, which is about 8 inches thick, when dry is light grayish yellow and weakly cemented into a firm but vesicular mass which readily breaks down into friable gritty loamy sand or sandy loam, and when wet is yellowish brown and somewhat coherent. The fifth layer, which is about 20 inches thick, consists of heavy fine sandy loam containing pockets of loamy sand and of heavy loam or sandy clay loam. When dry the pockets of sand are loosely friable, with a slight tendency toward induration, and when wet are slightly coherent. The material in the pockets of sandy clay loam is plastic and sticky when wet and forms irregular-shaped large structure masses when dry. This layer is thus made up of these variable

textured and structured masses and does not as a whole conform to one average texture or structure as do the layers above. The material in place is variable in color, being stained with gray, yellow, rust brown, and orange. The pulverized material is grayish yellow when dry and dark grayish brown when wet. Further varying the color are the black, pink, and white gravel and pebbles contained in the soil.

The sixth layer, below a depth of 40 or 45 inches, is fine sandy loam of single-grained structure in about one-third of its mass and of soft very fine granular structure in the remainder. When dry the soil is only slightly cemented, being loose and friable, and when wet it is only slightly coherent. There are no distinct pockets of variable textures as in the layer above. The color is grayish yellow or olive yellow, varied only by the varying colors of the gravel and stone present. The seventh layer, below an average depth between 50 and 60 inches, is similar to the layer above in all respects except the lighter color and greater proportion of very fine granular material. When dry the material is light grayish yellow and when wet is dark grayish yellow. With greater depth the soil presents much the same appearance but variations in texture, in content of gravel and stone, and in color, owing to variable mineralogical composition, are more pronounced. Another feature is the change from the acid reaction in the layers described to the alkaline reaction in the deeper parts of the less weathered soil material. This alkaline soil begins in most places at a depth of about 5 feet. (Pl. 1, A.)

The presence of bowlders and stone on the surface and embedded in the soil is a characteristic feature of Rockwood loam. Some of the softer rocks are partly disintegrated, which renders them easily shattered by slight pressure. The degree of acidity shown in the layers of the weathered soil and upper part of the parent material ranges from slight to strong.

Rockwood loam occupies the gently rolling land in the west-central part of the county and more or less isolated ridged positions on the outwash plains elsewhere in the county except in the southern tier of townships and in Bullard, Huntersville, and Shell River Townships, where none of this soil is mapped. Throughout the areas as mapped there are minor textural variations. In association with Rockwood sandy loam the soil is sandier in some layers, but is not lighter textured throughout, as is typical Rockwood sandy loam. Rockwood loam on the more rolling uplands bordering Leaf River Valley on the north in Leaf River Township is of this character. On lower slopes, adjacent to the Bluffton soils, Rockwood loam has a clay loam surface soil of darker color than typical. This constitutes the heavier-textured range of the soil. Again, in the extreme northwest corner of Red Eye Township is a variation showing the typical Rockwood substratum but a 3 or 4 foot covering of weathered uniformly mellow very fine sandy loam free from stone and pebbles and in many respects suggestive of a wind-deposited cover of well-assorted fine-textured soil materials. These areas were not of sufficient size to justify differentiation on a small-scale map.

Still another variation occurs on more or less well-defined level valley or terrace positions over an area of about 1 square mile in section 28 and adjacent sections of Red Eye Township. Here the substratum is more distinctly gravelly than typical. In position

this soil could well be considered an outwash terrace plain deposit, but surface bowlders and embedded stones are present in greater numbers than in the terrace soils, such as members of the Wadena and Menahga series. Had the gravelly layer occurred nearer the surface rather than at an average depth of 3 feet, this inclusion could well have been mapped in the Marquette series. A ridge of Rockwood loam in sections 15 and 16 of Red Eye Township, which includes an area of Marquette soil, has a stony gravelly subsoil.

Surface drainage is good on Rockwood loam because of the slope, but it is in no place erosive. The surface drainage water does not find its way directly into dissecting drainage ways, but issues into the depressed peat bogs of the region. Internal drainage is well regulated because of the absorptiveness but not too great retentiveness of the soil.

Most of the Rockwood loam is under cultivation, though tracts of woodland, some covering the greater part of a section, are scattered over the soil. The timber growth is that characteristic of the upland soils of the county. Little clearing has been done recently, as practically all farms have cropping acreages sufficient to engage the labor of the farm family. The labor of clearing this soil is heavy, owing to the presence of surface and embedded bowlders and to the thrifty well-rooted character of the timber growth. The remaining woodland tracts on most farms are not of any greater size than can at present be well utilized as woodland pastures and wood lots for windbreaks and fuel supply. Because of the stoniness of some of the uncleared areas it would seem unwise to improve them for cultivation. Few tracts, however, are so stony as to entirely prevent their use for cropping. Where the woods are fairly open there is a good stand of fine-stemmed pasture grasses. On the cultivated areas small or moderate quantities of stone, mostly small, are brought to the surface each year by plowing. These must be removed.

The Rockwood soils are recognized as the most productive of general crops in the county. They are well suited to corn, potatoes, small grains, clover, and alfalfa. The clovers do especially well. Occasionally two hay crops are obtained in a season, but as a rule only one hay crop is cut and the field is used for pasture the remainder of the season. This soil is not so early as the lighter-textured soils, but this is seldom a disadvantage except in unusually late springs and wet early summer seasons, when small grains are harmed, or in seasons of unusually early frosts, when the later-maturing or more tender crops, such as flax, late potatoes, and the more tender vegetables are injured. Rockwood loam is more drought resistant than the earlier lighter-textured soils, and satisfactory crop yields are as a rule much surer. The farms on Rockwood loam average between 120 and 140 acres in size. This is 10 or 15 acres smaller than the average for the county.

Sales of farms on this soil are not very numerous. In 16 recent sales the average price was $40 an acre, though some of the better-improved farms near markets commanded as high as $90 an acre.

Rockwood loam, poorly drained phase.—On foot-slope positions below the typical well-drained Rockwood soils some poorly drained areas or strips, in most places adjacent to peat bogs, have all the gen-

eral characteristics of the typical Rockwood soils except drainage conditions. Such areas have been mapped as Rockwood loam, poorly drained phase. As a rule the texture of the surface soil is variable, but in association with the sandier uplands of Orton Township it is loamy sand. In a few minor respects the soils of these areas differ from typical well-drained Rockwood soils. To a depth of 2 or 3 inches the surface soil is dark grayish brown or almost black when wet. The remainder of the surface soil shows the variegated coloring of the subsoil, the stains increasing in prominence with depth. The alkaline subsoil material occurs in most places at a depth of about 3 feet rather than 5 feet, as in typical Rockwood loam.

The poorly drained phase of Rockwood loam occupies positions similar to the Bluffton soils, but lacks the black surface soil and calcareous upper subsoil layer of soils of that series.

The areas of Rockwood loam, poorly drained phase, remain either in woodland or permanent pasture. No single areas are large enough to become of importance in the agriculture of any section of the county.

ROCKWOOD SANDY LOAM

Rockwood sandy loam consists of the following soil layers from the surface downward: (1) About a 2-inch layer of leaf mold and other organic matter; (2) about a 5-inch layer of very friable gray sandy loam somewhat stained with brown and rust brown; (3) about an 8-inch layer of grayish-yellow or yellowish-brown less friable sandy loam, which is slightly cemented in places; (4) about a 20-inch layer of varicolored loamy sand or sandy loam, stained profusely with rust brown, yellow, gray, and reddish brown. The soil of this layer is loose and permeable but very slightly cemented. Scattered pockets of clay, silt, and sand go to make up a variable-textured mass. Below an average depth of 40 inches there is little physical change, save for a more varied texture and more pocketed arrangement of masses of heavy and light textured material. A chemical change to an alkaline reaction occurs at a depth of about 5 feet; the soil above that depth ranges from slightly to strongly acid. Stones and some bowlders or partly disintegrated rock aggregates occur throughout the subsoil, and the surface is marked by the presence of embedded or surface bowlders in moderate numbers. Some small tracts are thickly bowlder strewn. This soil is similar to Rockwood loam, except in having a lighter-textured surface soil, generally though not everywhere a correspondingly lighter subsoil, and a greater number of stones and pebbles throughout.

Rockwood sandy loam occurs on the rolling uplands of the county over which Rockwood loam is the principal soil. The sandy loam commonly occupies the more rolling areas, occurring at higher elevations on narrow rounded crests or at lower elevations on slopes from the broader crests of the loam soil. A considerable area of Rockwood sandy loam occurs in the west-central part of the county outside this rather distinct region of occurrence of Rockwood loam. In the northeast and north-central parts of the county this soil is associated with the lighter-textured Kinghurst upland soils. In such areas it has a loamy sand texture similar to that of Rockwood

loamy sand to a depth of a foot or two. The presence of the heavier-textured subsoil distinguishes it from the Kinghurst soils not only on examination of the soil itself but distinctly in wooded areas in the greater proportion of hardwoods on the Rockwood soil. Still another distinct occurrence of Rockwood sandy loam is on the comparatively small elevated ridges and knolls on the terrace outwash plains. The largest of these are in Aldrich Township south and east of Partridge River, and smaller ridges are well distributed over the remainder of the plain occupied by the Wadena soils in the southern part of the county. Similar ridges of Rockwood sandy loam occur on the plains where the Menahga and Nymore soils are dominant, but these areas are smaller, less numerous, more variable in texture, and less bowldery than typical. These ridges commonly include soils of the Marquette and Kinghurst series and areas of Rockwood loamy sand. A fourth very minor occurrence of Rockwood sandy loam is on the eroded slopes of the outwash terrace along Leaf River where, in small areas, the variable-textured bowldery Rockwood substratum is exposed. These four distinct occurrences of Rockwood sandy loam give this soil a distribution over practically all parts of the county.

In addition to the soil variations brought out in the preceding paragraph a few others are worthy of mention. One inclusion is of very mixed soil comprising small gravelly knolls of Marquette sandy loam. These areas are very bowldery and, though of variable texture, average sandy loam. In some places they differ from Rockwood loamy sand only in containing a greater number of clay and silt masses in the subsoil. They are more hillocky and sloping or rolling than typical Rockwood sandy loam. Such areas occur on a well-defined ridge along Kitten Creek and in section 5 in Red Eye Township and in sections 29, 30, and 32 of Blueberry Township. Also, as in Rockwood loam on level or undulating areas, there is a gravelly subsoil variation of Rockwood sandy loam in Red Eye Township.

Surface drainage of Rockwood sandy loam is well developed and efficient because of the gently rolling relief. A few of the steeper slopes, especially those below the bluffs of the more deeply dissected main stream valleys, are somewhat erosive. Internal drainage is well regulated, but the lighter texture of this soil is apt to cause it to be somewhat more droughty than Rockwood loam when moisture supplies are low.

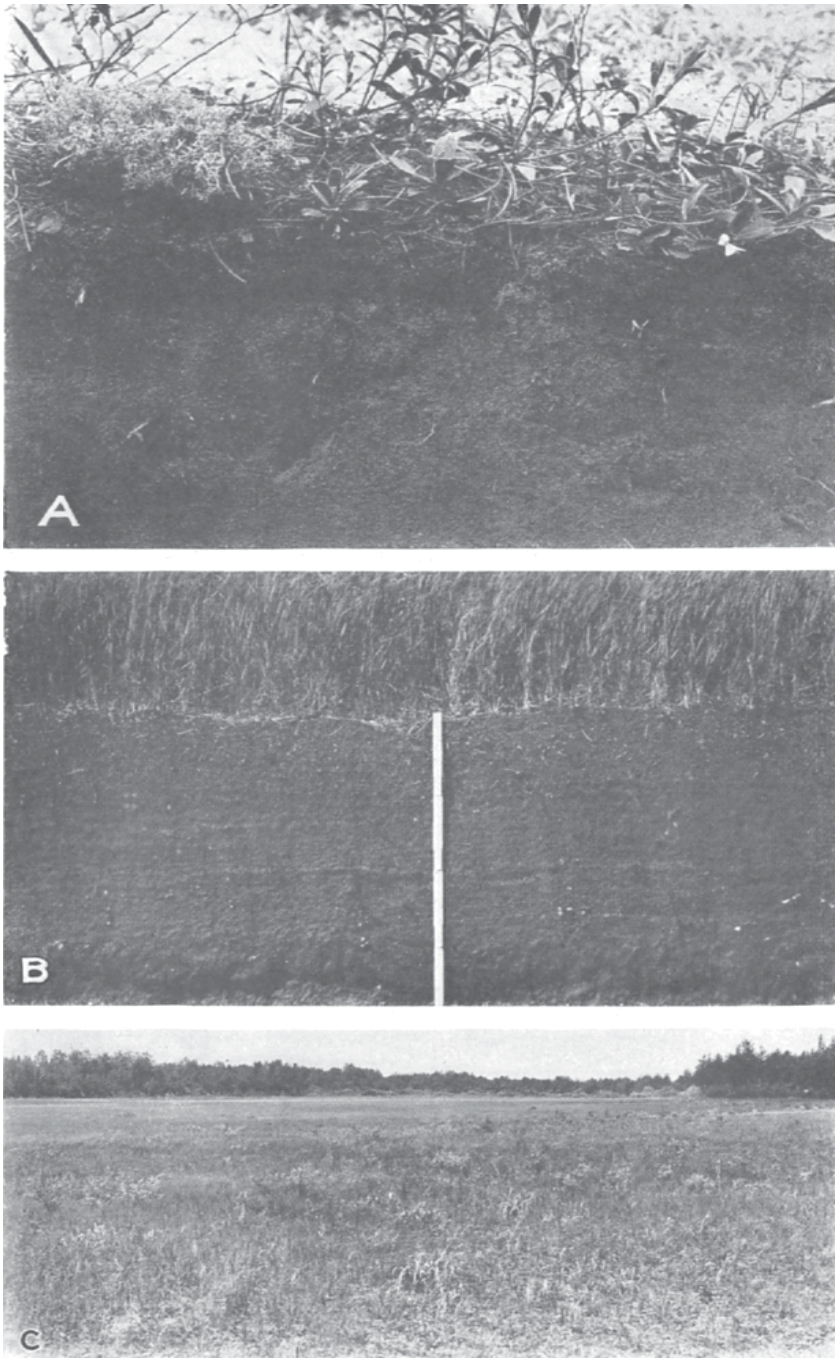
Natural vegetation on Rockwood sandy loam is similar to that on the loam, except that the proportion of conifers is slightly greater. Grass of pasture value makes a good stand in the more open woodlands. A greater proportion of Rockwood sandy loam is in woodland than of Rockwood loam. Farms are less well improved, crop acreages smaller, and farming operations on a smaller scale.

Six of the most recent sales of Rockwood sandy loam show an average price of $27 an acre. The highest price was $55 an acre.

ROCKWOOD LOAMY SAND

Rockwood loamy sand consists of the following soil layers from the surface downward: (1) About a 3-inch layer of leaf mold, grass,

A, Profile of Rockwood loam showing the loose loamy upper layers, the heavier darker-colored subsoil, and the firm medium-textured glacial till substratum; B, young second-growth jack pine on an abandoned field, characteristic of Nymore and Menahga soils



A, Surface layers of Menahga sand, showing characteristic ground cover; B, profile of Badoura peat showing characteristic grass vegetation and lack of woody material; C, open grass vegetation on bog of Badoura peat

and humus; (2) about a 4-inch layer of grayish-brown loamy sand, with some rather dark organic stains, which when moist is moderately coherent and dark grayish brown and when dry is moderately loose, with a fragile fine granular structure; (3) about a 30-inch layer of loose loamy sand, containing some small stone and gravel, the mass being almost entirely of single-grained structure with a mass color of light grayish yellow when dry and dark yellowish brown when wet; and (4) below an average depth of 38 inches, slightly more coherent heavy loamy sand or sandy loam of no particular mass color but much stained with brown, gray, bluish gray, and deep red. This extends to a depth of about 4 feet without change, but there the texture becomes variable and clay, silt, and sand pockets similar to those in the typical subsoil of the heavier Rockwood soils appear. Almost directly below this layer the substratum becomes alkaline in reaction, whereas the layers above are slightly or strongly acid. In most places bowlders are embedded in the soil and strewn on the surface in moderate numbers, but in some spots they are very numerous.

In texture profile Rockwood loamy sand resembles Kinghurst loamy sand, but the Rockwood soil differs in being darker colored in the surface layer, in showing color stains nearer the surface and more conspicuously in the deep subsoil, and in being thinner above the heavier more variable-textured substratum.

Rockwood loamy sand occupies a variety of positions and is well distributed over the county. It occurs on ridges elevated above the level outwash plains, on ridges in the rolling uplands, and on the bluff crests of these uplands adjacent to stream valleys and depressed areas. In other places it occupies slopes below Rockwood sandy loam and Rockwood loam or Kinghurst loamy sand. It is commonly associated with these three soils on the same ridge formation, in few places composing the whole of any one ridge. Boundaries between these soils are arbitrarily drawn in many places. In sections 17, 18, and 20 of Wing River Township on the bluff lands to the north of Leaf River Valley an area of Rockwood loamy sand is finer in texture than typical and is a little freer of bowlders and stone on the surface and to a depth of 3 or 4 feet. Many soil profiles in this area show the soil to be a uniform loamy fine sand with a color profile and reaction profile typical of the Rockwood soils.

Surface drainage of Rockwood loamy sand is well regulated, and in only a few places on the more abrupt slopes is it erosive. Internal drainage is a little too rapid to allow sufficient moisture to be retained to render the soil drought resistant. The natural vegetation is largely of aspen, oak, and pine, with the hardwood species predominating as a rule.

About seven-eighths of this soil is in woodland pasture and one-eighth in cultivation. Farmers recognize that crops are subject to damage by drought but consider the soil's earliness an offsetting advantage. Cultivated crops, where it is possible to preserve a good mulch surface, are little harmed by any but severe droughts.

Few if any sales of Rockwood loamy sand have occurred recently and no set valuation can well be made. The soil is held in a little lower favor than Rockwood sandy loam, however.

KINGHURST LOAMY SAND

In Kinghurst loamy sand a thin covering of leaf litter, consisting chiefly of pine needles, is on the surface. This is underlain by about a 10-inch layer of brownish-gray loamy sand which when wet has a dark grayish-brown color. The soil is single grained, with a scattering of small soft granular masses. When wet, the material is very slightly coherent. The third layer, to a depth of about 24 inches, consists of loamy sand which when dry is grayish brown and when wet is dark brown. Faint yellow and gray stains, brown organic stains, and different-colored sands, the most conspicuous of which are black, white, and reddish brown, vary the color. The fourth layer, below an average depth of 37 inches, is light yellowish-brown loamy sand or sandy loam which when wet is dark yellowish brown. With depth the texture becomes more variable, because of the presence of numerous small pockets of heavy and light texture. The less weathered substratum is of the same color as in the Rockwood soils but averages lighter in texture and more porous in consistence to a depth of at least 5 feet and in many places much more.

The first four layers described are medium or strongly acid in all places. Bowlders and stone occur on the surface and embedded in the soil, ordinarily being less numerous in the upper three layers than in the fourth layer and substratum. Surface bowlders are usually not so numerous as on the Rockwood soils.

Kinghurst loamy sand differs from Menahga loamy sand chiefly in that more bowlders are scattered on the surface, the substratum is of heavier texture, and a stained coloration of the subsoil is noticeable. Where the evidence of these differences is scant, boundaries between these soils are arbitrary. The positions of the Kinghurst soil on higher and somewhat undulating areas in contrast to the more level plain position of the Menahga soils is not in all places plainly marked. Thus in Lyons Township adjacent to the Crow Wing River Valley north of Oylen Kinghurst soils are of little apparent difference in elevation from the Menahga soils farther back from the river.

The greater part of this soil occurs on the gently rolling ridged uplands of Orton and Lyons Townships. Areas also occur on isolated ridges on the leveled outwash plains of Menahga soils and on other ridges similarly surrounded by peat-bog depressions. The soil occurs in all parts of the county except the southern tier of townships and the region of Rockwood loam in Rockwood Township.

In Kinghurst loamy sand the variations from typical are for the most part minor textural variations and varying thicknesses of the different soil layers. A 1 or 2 foot covering of loose sand rather than loamy sand is the difference most extensively noted. Much of this soil in Orton Township is of this character. Variations in the surface soil to loamy fine sand or sandy loam are less extensive.

The natural drainage of Kinghurst loamy sand is too thoroughly developed to preserve proper soil moisture for crops during dry spells. The loss of moisture is caused almost entirely by the porosity of the soils rather than by run-off. The heavier substratum at a depth of 5 or 6 feet checks the percolation of water to some extent, but this advantage seems only slightly apparent on crops and shallow-rooted plants. In the tree growth, however, a greater thrifti-

ness and more Norway pine and hardwood trees are noted than on the deeper sandy soils of the Menahga series. The underbrush and grass growth is scant, but in some openings the grass stand becomes fairly luxuriant.

The area of Kinghurst loamy sand improved for cropping is comparatively small, the greater part of the soil being in woodland which furnishes rather scant pasturage. Cropping and stock raising are carried on on a comparatively small scale.

In 8 or 10 sales of this soil in the years 1925 and 1926 the average price was about $15 an acre.

ALDRICH LOAMY SAND

Aldrich loamy sand has a thin surface covering of leaf mold, grass litter, and humus. Below this the main surface soil layer, about 6 inches thick, consists of loamy sand, very dark grayish brown or dark gray when dry and darkening more nearly to black when wet. The soil mass is single grained, with a few very fragile and weakly cemented fine granules. When wet the mass is moderately coherent.

The third layer is about 10 inches thick and consists of dark grayish-brown loamy sand which when wet appears dark brown. The structure is largely single grained, with some fine granules larger than those found in the surface layer and more firmly cemented though still fragile. When wet the mass is moderately coherent, with a suggestion of stickiness. The next lower material, between average depths of 20 and 40 inches, is pervious loamy sand largely of single-grained structure but with fragile granular aggregates a little larger than those in the layer above, ranging from one-eighth to one-half inch in diameter. When wet this layer is moderately coherent, with a suggestion of stickiness. When dry the color of the single-grained mass and exterior of the granules is light grayish brown and when wet is dark yellowish brown. Faintly apparent in the single-grained mass but more pronounced in the breakage surfaces of the structure aggregates are stains of gray, yellow, rust brown, and reddish brown. The fifth layer, below an average depth of 40 inches, is a mass of unassorted glacial till, loamy sand or sandy loam in texture, containing gravel and medium or large sized stones. When wet the mass is moderately coherent and slightly sticky. The variation in color stains, such as are in the layer above, appear more emphasized in this layer with less of one color prevailing. The pulverized soil mass when dry is light or dark yellowish brown and when wet is dark yellow.

With depth the less weathered materials appear more variable in texture, ranging from loamy sand to clay loam. These lighter and heavier textured materials occur in pockets. The soil appears to be the result of the weathering of materials of two distinct geologic deposits. The upper soil layers, to a depth of about 40 inches, are derived from assorted material, probably water-laid, and the lower layers from unassorted ice-laid till. On the basis of points of similarity and of occurrence in intermediate positions between the two, Aldrich loamy sand may be considered a transition soil between the Rockwood soils and lighter-colored soils of the outwash plain, such as the Menahga.

As is true in most soils transitional between two or more soils of more definite character, areas of Aldrich loamy sand include varia-

tions from typical. In many of the areas occurring in association with the Rockwood soils the two surface layers are much heavier textured than typical, being sandy loam in the surface layer and heavy sandy loam in the layer below. Such areas show greater moisture-retaining properties than the typical soil and often have darker-colored surface soils. They may also have more gravelly subsoils. The gravel may be collected in the upper part of the subsoil in a thin layer, but it is most commonly distributed evenly throughout the layer. An area in section 33 of Red Eye Township embodies all three of these variations, that is, the sandy loam texture, the darker surface color, and the gravelly subsoil. In association with the Kinghurst soils, the soil may be lighter colored, lighter textured, and more porous than typical, closely resembling Kinghurst loamy sand. The tendency of the second layer to greater compactness is usually noticeable in this lighter-textured variation. Also the substratum of drift materials is a little more sandy and porous than in areas adjacent to the Rockwood soils. Certain parts of the Aldrich soil areas show a lack of this drift material, in the substratum at least, and topographically resemble a typical outwash plain. Even lacking concrete evidence of drift influence in the substratum, the soil with its grayish surface soil and stained subsoil more closely resembles the Aldrich than the Nymore or Menahga soils.

Aldrich loamy sand occupies areas sloping gently from higher ridges of Rockwood and Kinghurst soils, and also level or undulating parts of adjacent outwash plains. The areas are practically undissected by natural drainage ways, the little surface drainage being only such as is afforded by surface slope. Internal drainage is thorough, except where soil layers or substrata are more retentive of moisture than typical.

About two-thirds of the soil is woodland. It occupies only a very minor part of any single farm and is considered less productive than the Rockwood soils but a little more productive than the Nymore and Menahga soils. The sandy loam areas included with the loamy sand yield almost as heavily as Wadena sandy loam.

WADENA SANDY LOAM

Wadena sandy loam has a thin surface layer of dark-colored organic matter, underlain by a 10-inch layer of very dark grayish-brown sandy loam which when wet appears almost black. This material is single grained or fine granular in structure, the granules being moderately coherent and hard when dry. The soil mass is loose and friable when dry and is somewhat coherent but still friable when moist. The third layer, which is 10 inches thick, is heavy sandy loam, brown when dry and somewhat reddish brown and darker when wet. This material is granular, the granules being firm and moderately hard. When wet it is moderately tenacious and somewhat sticky and plastic. Below this layer is a 16-inch layer of loose loamy sand or sand containing considerable fine and coarse gravel. Its color is dark yellowish brown, becoming darker when wet. This mass color is variegated in many places by faint stains of yellow and rust brown. When moist the material acquires very little coherence and maintains its single-grained structure. It

is underlain, below an average depth of 40 inches, by gray or light grayish-yellow loose sand containing small amounts of gravel and coarse sand. This material appears only slightly darker when moist, and the color is less variegated by stains than in the layer above. The reaction is alkaline, sufficient lime carbonate to effervesce in dilute hydrochloric acid being present. The material is of mixed lithologic composition. Quartz is the most abundant mineral, but there are distinctly visible fragments of granitic rocks and feldspathic and ferromagnesian minerals.

The upper soil layers are moderately retentive of moisture, but the sand substratum beneath is porous and permeable. The reaction of the soil above the alkaline fifth layer is slightly or strongly acid, but parts or all of the fourth layer directly overlying the alkaline layer may be neutral or slightly alkaline. The soil is free of surface or embedded bowlders, but small stones 6 inches or less in diameter are numerous in a few places. The sand grains, which range in size from very fine to coarse, are noticeably sharp and angular in all the layers.

Minor variations, chiefly in the thickness of the soil layers and in texture and structure, have been included. The surface layer of black organic soil is in places only 8 inches thick and lighter colored than typical. These conditions are most noticeable in areas adjacent to the lighter-colored soils of the Menahga and Central series, but occur elsewhere on small ridges or knoll crests and steeper slopes where slope wash has thinned the surface layer. The brown subsoil layer is exposed in plowed fields of these lighter-colored areas. Besides differing in thickness and color, the black surface layer ranges in texture from loamy fine sand to coarse sandy loam and loam. In general the sandier-textured areas occur on slight elevations on the plain and the finer or loamier textured areas on flatter positions. The brown subsoil layer ranges from 2 to 20 inches in thickness and contains variable proportions of clay and silt which alter the degree of stickiness when moist. A thin but stickier brown layer, often of reddish color, occurs in many places underneath a shallow surface soil on the more rolling areas. A thin brown layer, both lighter textured and less coherent than typical, is common in areas near the loamy sand soils, and a thick brown layer, everywhere as coherent or more coherent than typical, occurs on the flatter areas adjacent to Wadena loam or the lower-lying Granby soils. In areas associated with the more poorly drained Granby soils the two lower layers of the typical soil are more distinctly stained or variegated in color than typical.

Wadena sandy loam occurs on a gently undulating plain. The undulations afford moderate surface drainage, but the greater part of the moisture is absorbed by the soil which, because of the moisture-holding capacity of the upper layers, is only slightly droughty in spite of the porosity of the substratum.

Wadena sandy loam extends in a comparatively uniform and unbroken area over the whole of Wadena and Aldrich Townships and the western and southern parts of Thomastown Township. It has a distinct regional occurrence, being practically limited to that section lying south of Leaf River and west of Crow Wing River. The largest area outside this region is in the center of Wing River Township.

The very dark color and thickness of the upper layers of Wadena sandy loam indicate that this soil supported, for a considerable period, a fairly dense grass stand; the decayed grass roots have imparted the characteristic black color. It is known, however, that in places there was, at the time of settlement, brush and timber growth. A few such areas remain, but the greater part of this soil is now cultivated.

Farms on Wadena sandy loam average about 160 acres in extent and are well improved for cropping, only small plots for windbreaks and shelter remaining wooded. Hog raising is given more attention than elsewhere in the county. The crop acreage to the farm is larger than on any other soil mapped. In dry seasons the Wadena soils are recognized as less productive than the Rockwood, particularly of clover. The greater improvement of the Wadena soils, as compared to the Rockwood, is owing as much or more to the greater ease of clearing this land and to its location nearer to the first-settled markets of the county as to any greater degree of productiveness of the soil.

In market value farms on Wadena sandy loam with their better improvements rank higher than those on other soils. About 20 sales during 1925 and 1926 indicate an average market value of about $55 an acre; some farms brought $100 or more an acre.

Table 4 shows the results of mechanical analyses of samples of the surface soil, subsurface soil, and several layers of the subsoil of Wadena sandy loam.

TABLE 4.—*Mechanical analysis of Wadena sandy loam*[1]

No.	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
321982	Surface soil, 0 to 3 inches	3.1	19.4	14.8	28.4	6.7	22.7	5.3
321983	Subsurface soil, 3 to 13 inches	11.1	41.4	8.7	8.0	3.4	21.3	6.2
321984	Subsoil, 13 to 23 inches	8.1	42.1	9.0	6.0	4.6	22.6	7.4
321985	Subsoil, 23 to 39 inches	22.3	63.3	9.3	2.9	.2	2.0	.0
321986	Subsoil, 39+ inches	1.4	15.6	46.9	32.1	2.0	.2	1.7

[1] After treatment with hydrogen peroxide.

WADENA LOAMY SAND

Wadena loamy sand is similar to Wadena sandy loam in number, arrangement, and color of the soil layers from the surface downward. The outstanding difference is in the lighter or sandier texture of the second and third layers. The second layer, which constitutes the main body of the topsoil or plow soil, is very dark-colored loamy sand rather than sandy loam; the third layer, commonly known as the subsoil, contains much less clay and is less coherent and more permeable than the corresponding layer in Wadena sandy loam. The substratum material, comprising the fourth and fifth layers, is loose sand with, in general, a smaller proportion of gravel and a higher proportion of quartz grains than is typical of the substratum material of Wadena sandy loam.

The upper four layers show slight or medium acidity; the fifth layer, which occurs at an average depth of 4 feet, is alkaline, the alkalinity increasing in most places with depth. The soil is bowlder

free, but in places small rocks are present on the surface and embedded in the soil.

Wadena loamy sand conforms in general to the description given. The principal variations observed were in texture and thickness of the respective soil layers. The areas occupying the first or lower terrace positions adjacent to the streams generally show a black surface layer from 2 to 5 inches thicker than that in the typical soil, and lower layers less perceptibly different from one another in texture and containing smaller amounts of coarse particles such as gravel. In few places is the gravel more abundant in any one layer than in the others, as it is in the third layer in typical areas. Very minor included areas on small rather abrupt knolls and ridges are coarse loamy sand or sand in texture. Such areas have a lighter or more brownish surface soil than typical.

Wadena loamy sand occupies the more rolling areas on the borders of the undulating outwash plain adjacent to the streams. Smaller areas on the plain proper are elevated slightly above the surrounding levels. These elevations have gentle slopes and broad crests. Over the land as a whole there is a little more surface run-off than on Wadena sandy loam. This, together with a little more active internal drainage caused by the absence of a noticeably heavier subsoil layer, such as is present in the sandy loam, makes Wadena loamy sand a little more droughty and excessively drained than that soil.

The natural vegetation on Wadena loamy sand was similar to that on the sandy loam in the more rolling areas. A comparison of the present unimproved pastures and woodlands on these two soils shows the loamy sand supports more tree growth (jack pine and oak) and less brush (hazel principally) and a less dense grass stand than the sandy loam.

About 15 per cent of the Wadena loamy sand is in woodland pasture and the remainder is devoted to crops. A few of the larger areas compose whole farms. The greater part of the soil, however, is in smaller areas which make up only a minor part of any one farm. Wadena loamy sand is recognized as less productive than Wadena sandy loam in dry seasons, but little inferior in wet or normal seasons. The finer-textured areas are sometimes subject to drifting, but seldom is this so severe that a mulch surface can not be maintained under proper cultivation.

The market value of this soil is usually a little lower than that of Wadena sandy loam. In 10 sales during 1925 and 1926 the average price was about $40 an acre.

Table 5 shows the results of mechanical analyses of samples of the surface soil, subsurface soil, and several layers of the subsoil of Wadena loamy sand.

TABLE 5.—*Mechanical analysis of Wadena loamy sand*

No.	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
321977	Surface soil, 0 to 3 inches	2.4	24.7	21.6	32.9	4.0	12.0	2.3
321978	Subsurface soil, 3 to 13 inches	3.8	39.5	23.8	22.0	2.0	7.2	1.7
321979	Subsoil, 13 to 21 inches	3.6	32.6	24.5	26.9	2.6	7.8	2.3
321980	Subsoil, 21 to 51 inches	7.8	50.9	24.1	14.9	.4	1.4	.9
321981	Subsoil, 51+ inches	32.9	34.8	14.7	15.5	.7	.6	1.0

WADENA LOAMY FINE SAND

Wadena loamy fine sand is similar in all soil characteristics to Wadena loamy sand, except that the upper layers carry a greater proportion of fine sand, with smaller amounts of the medium and coarse grades.

This soil is inextensive. It occurs as small isolated areas in the southern part of the county in association with the other Wadena soils. Owing to the fine texture of the surface layers, it may have a somewhat better moisture-holding capacity than Wadena loamy sand and be regarded, on that account, as a slightly better agricultural soil.

WADENA LOAM

Typical undisturbed Wadena loam has a thin covering of organic matter, underlain by an 8-inch layer of very dark grayish-brown loam which when wet appears almost black. The mass breaks readily into small granules, which are soft when moist but on drying become hard. When wet, the soil mass is moderately tenacious, but under average field moisture conditions is friable and tractable. The next lower layer, which is about 8 inches thick, is dark-brown heavy loam or clay loam appearing darker in color when wet. The mass breaks into granules somewhat more distinct and harder when dry than those formed in the layer above. When wet, the layer is moderately plastic and somewhat stiff.

The fourth layer, about 8 inches thick, consists of clay loam, generally brown slightly mottled with rust brown and yellow. This material is of very fine granular structure. The granules become hard and well cemented on drying. When moist the layer is rather friable but when wet it becomes tenacious and moderately plastic. This layer, more than any above or below it, shows this characteristic. The next lower layer, which ranges in thickness from about 14 to 20 inches, consists of gravelly sand or coarse sand, coarsely gravelly and stony with some interstitial clay in the upper 4 or 5 inches, but becoming more uniformly fine gravelly sand or coarse sand with depth. The dry mass is brown or yellowish brown, varied by the different colors of the gravel particles. When wet, the color becomes darker brown. A very few coarse granules, formed by aggregation of the soil material, are present, chiefly in the more clayey gravel in the upper part of the layer. The layer as a whole is loose and permeable, assuming but little coherence when wet.

The sixth layer, below an average depth of 48 inches, is light grayish-yellow, loose, incoherent, fine gravelly sand or coarse sand, which when wet assumes a dull-brownish tinge. The gravel and pebbles do not lose their variable colors in this layer. The soil mass when wet has little or no coherence. The layers above this show slight or medium acidity, but the sixth layer is alkaline. With depth the less well-weathered materials have essentially the appearance of the last-described layer, though textures and color are more variable. No bowlders are on the surface or embedded in the soil, but small rocks are present in varying quantities. The sand particles of the various layers are unassorted as to size and have sharp angular edges. The sandy gravelly subsoil layers are fully as pervious as

the same layers in the other Wadena soils, but Wadena loam has much more retentive soil layers above the porous substratum.

The most noticeable variations from typical are in the depth to the sand and gravel substratum. In small spots, generally most numerous on slight knolls and slopes, the black surface layer is only about 8 inches thick and the brown clay loam subsoil 6 inches thick, so that the gravelly substratum begins at a depth of only 14 inches. Such soil is widely distributed in small areas. Of similar distribution but usually occurring on the flatter or slightly depressed areas is a soil in which the gravel begins at a depth of about 36 inches and in which the material between this gravel and the black surface soil is clay loam or silty clay loam heavier than typical. This inclusion resembles the Granby soils but lacks the intensity of mottling or staining present in those soils. Such a variation is most in evidence in the large area in southeastern Wadena Township and in the area in sections 30 and 31 of Leaf River Township. The area in Wadena Township presents some evidence of the presence of a deep substratum of till, such as underlies the Rockwood soils. In fact, the Rockwood soils occur a little to the east on only slightly elevated areas and on slopes from the plain level to small drainage ways. This seems to indicate the presence of underlying Rockwood parent soil material. Other small included areas are of the other Wadena soils and of the Granby soils.

Wadena loam occurs on parts of the large plain of Wadena soils in Wadena Township, in the southwestern corner of Aldrich Township, and in sections 30 and 31 of Leaf River Township. These areas show a relief somewhat flatter and less undulating than that of the plain as a whole. Surface drainage is but little developed, and internal drainage is well regulated by the retentive layers above the loose gravel substratum. Thus these areas are able to resist longer and more severe periods of drought than the other Wadena soils and are almost as drought resistant as Rockwood loam.

Practically the whole area of Wadena loam is cleared and under cultivation. The soil occurs in comparatively broad areas, which compose all or the greater part of a number of farms. In state of improvement and productiveness it ranks as high as Wadena sandy loam and is considered a little more productive than that soil in dry seasons. The cropping systems are practically the same as on the other Wadena soils and values are similar, though possibly this soil commands a little higher price than Wadena sandy loam.

CENTRAL LOAMY SAND

The surface soil of Central loamy sand, to a depth of 6 or 8 inches, is very dark grayish-brown loamy sand, which appears almost black when wet. When moist or wet, the soil mass is moderately coherent. A 10-inch layer below this is brown heavy loamy sand appearing dark brown when wet and becoming slightly coherent and sticky. The next lower material is loose incoherent sand ranging from yellowish brown in the upper part to light grayish yellow at a depth of 4½ or 5 feet. When wet, the material is somewhat darker and shows very slight coherence. The sand particles are fairly uniform in size and have rather sharp angular edges. Gravel in small amounts is

distributed throughout the loose sand substratum. The soil is free of bowlders, but small rocks and stone are found in some places. The reaction is from slightly to strongly acid to a depth of 4 or 5 feet; below this depth the material is alkaline and effervesces in dilute hydrochloric acid, indicating the presence of free lime carbonate.

Central loamy sand differs from Nymore loamy sand mainly in that the alkaline substratum occurs nearer the surface. The main differences between Central loamy sand and Wadena loamy sand are the shallower black surface layer, lighter-colored sandy subsoil, and greater depth to alkaline soil materials in the Central soil.

Some areas of Central loamy sand show distinct but minor variations from typical. On low elevated knolls or ridges, most of which are surrounded by low-lying depressed areas in the outwash plain, the surface soil is lighter in color and coarser in texture, in many places containing some gravel. The lower layers are also coarser in texture. Such land occurs in section 14 of Aldrich Township and in sections 31 and 32 of Thomastown Township. Boundaries between this soil and Wadena loamy sand in many places were difficult to determine and arbitrarily drawn.

Central loamy sand occurs in association with Wadena loamy sand on the gently rolling lands which border the stream valleys of the outwash plain in the two southern tiers of townships. Surface drainage is well developed, but seldom erosive. The soil is absorptive, but not so retentive of moisture as the Wadena soils, although it is more retentive than Menahga loamy sand.

Less than one-third of this soil is wooded; the greater part is in cultivation or improved pasture. The soil composes the whole of very few farms, in most places occupying only a very minor part of the farms. For agricultural purposes Central loamy sand is considered inferior to Wadena loamy sand, but superior to Menahga loamy sand. Its market value also is intermediate between those of the two soils mentioned.

CENTRAL SANDY LOAM

Central sandy loam has a thin surface layer of dark-colored organic matter, underlain by about a 5-inch layer of loamy sand or sandy loam, which when dry is very dark grayish brown and when wet is almost black and slightly coherent. The third layer, which is about 13 inches thick, consists of brown loam or clay loam, which when wet assumes a chocolate-brown color. The soil mass is granular. The granules are rather hard when dry, making the mass friable and crumbly. When wet, it is coherent and more stiff and sticky than the layers above or below. It is underlain by a layer, about 9 inches thick, of loose gravelly sand with sufficient fine material to impart slight coherence to the mass when wet. Under normally moist or dry soil-moisture conditions this material is loose and permeable. The soil mass is partly very finely granular, the granules being hard. The color of this layer is yellowish brown or brown, when wet becoming more chocolate brown.

The fifth layer, which is 9 inches thick, is loose sand of more uniform texture than the layer above. When dry the color is yellowish brown and when wet is darker yellowish brown. The soil mass

on drying tends to form a few structure granules or particles which are very soft, fragile, and easily shattered into the component soil particles. When wet the mass is very slightly coherent. The sixth layer, below an average depth of 38 or 40 inches, is light grayish-yellow or light yellowish-brown, loose, very permeable sand of single-grained structure and showing no appreciable coherence even when moist. The less weathered materials at greater depths show more variable sandy textures and color, but are, in the main, similar to the layer above.

All the soil layers, except the sand layer, are acid. The upper foot of the sand layer is in most places neutral and the material below an average depth of about 4 feet is alkaline.

Central sandy loam is free of bowlders, but contains small numbers of small rocks and stones in places. The soil is very similar to Wadena sandy loam, the main differences being the thinner black surface layer and the lighter-colored loose sandy subsoil layers of the Central soil. Although the heavy subsoil layer is little different in the two soils, the Central soil shows this layer in more definite contrast to the layers above and below, because of a more abrupt transition between the layers. The depth at which the soil material is alkaline varies in both the Wadena and Central soils.

Central sandy loam occupies small gently rolling areas and is most common on the parts of the outwash plain adjacent to stream valleys or lower terrace escarpments. The soil occurs in close association with the Wadena soils. A few areas, mainly in somewhat depressed or level positions within a plain of lighter-colored soils, principally the Nymore soils, are very gently undulating. Such an area occurs on the east county line in section 13 of Thomastown Township. About three-fourths of the soil is cleared and cultivated.

Natural drainage of Central sandy loam is fairly favorable to crop production, except that crops suffer from drought during dry seasons or periods. The two surface layers retain moisture well before it reaches the porous substratum, but considerable precipitation is unabsorbed by these layers owing to run-off. Soil moisture conditions are not quite so well maintained as in Wadena sandy loam, owing to the thinner surface and subsoil layers of the Central soil as well as to the greater surface run-off. As an exception, the more level and depressed areas in association with the Menahga soils absorb and retain more of the precipitation and in places show excessive moisture conditions for short periods after rain. The less well-aerated slightly mottled appearance of the subsoils reflects this condition.

In productiveness Central sandy loam is considered a little inferior to Wadena sandy loam and superior to Central loamy sand.

HUBBARD SANDY LOAM

Hubbard sandy loam has about a 1-inch covering of grass litter and humus, underlain by about a 10-inch layer of very dark grayish-brown sandy loam appearing almost black when wet. The structure is single grained and in part very finely granular, the granules being very small and rather soft. The soil mass is very friable when dry and somewhat coherent though still friable when wet. The

next lower layer, about 9 inches thick, is brown sandy loam appearing somewhat red when wet. The structure is more granular than in the layer above, and the granules are a trifle larger and a little harder and less fragile. The soil mass is rather hard when dry and when wet assumes a slight stickiness and a little greater tenacity than the layer above. The fourth layer, about 20 inches thick, is yellowish-brown loamy sand which when wet appears darker in color. Small amounts of fine gravel are present in this layer, which is rather loose and porous and when wet assumes only slight coherence.

The fifth layer, below an average depth of 40 inches, is loose porous light grayish-yellow fine sand or sand becoming dark grayish yellow when moist. The structure is entirely single grained, and the soil mass has little coherence even when wet.

This soil is generally free of bowlders, though small stones are present in places on the surface and in the soil. The reaction is acid in all the upper layers, but the sandy substratum material is neutral or alkaline below a depth of 25 or 30 inches and generally contains lime carbonate below a depth of 60 or 70 inches.

Hubbard sandy loam in Wadena County occurs only in a narrow strip on the northern boundary. This is the extreme southern fringe of a large plain of these soils which occurs in Hubbard County to the north. The land is level or gently undulating and occupies glacial outwash plains. Little dissecting drainage has developed, and surface drainage is only that afforded by slope wash. The upper two layers are absorptive and moderately retentive of rainfall, but percolation through the substratum is rapid, resulting in an insufficient moisture supply for crops during dry spells.

This soil is entirely cleared and in cultivation. In productiveness, system of management, and present state of cultivation and improvement it is similar to Wadena sandy loam.

Table 6 shows the results of mechanical analyses of samples of the surface soil, subsurface soil, and subsoil of Hubbard sandy loam.

TABLE 6.—*Mechanical analysis of Hubbard sandy loam* [1]

No.	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
321933	Surface soil, 0 to 2 inches	3.2	21.0	16.9	29.8	5.9	15.8	7.8
321934	Subsurface soil, 2 to 14 inches	5.6	24.6	19.0	32.3	4.6	10.0	4.3
321935	Subsoil, 14 to 17 inches	4.6	24.0	17.7	30.7	6.0	11.5	5.9
321936	Subsoil, 17 to 23 inches	5.0	23.2	17.1	32.6	6.9	10.3	5.1
321937	Subsoil, 23 to 42 inches	3.6	18.0	27.9	41.3	5.5	1.7	2.4
321938	Subsoil, 42 to 54 inches	.1	10.2	18.0	66.9	3.0	.5	.3
321939	Subsoil, 54+inches	6.8	38.0	17.2	36.3	1.0	.4	.6

[1] Much of the "clay" fraction of the surface layer is organic matter rather than mineral clay.

NYMORE LOAMY SAND

Nymore loamy sand has a covering of pine needles, leaf mold from deciduous trees, and other organic matter, underlain by about a 15-inch layer of very dark grayish-brown loamy sand appearing almost black when wet. The color is speckled with the light color of clear quartz sand grains. The structure is largely single grained.

At all stages of moisture the soil is friable. It is only moderately coherent when wet and moderately loose when dry.

The next lower layer, about 9 inches thick, is brown heavy loamy sand which assumes a darker color with a slightly red hue when wet. The mass, on drying, forms structure particles of variable size, ranging from one-eighth inch to 2 inches in diameter. These particles are slightly hard when dry. When wet this soil layer is moderately coherent and slightly plastic and sticky.

The fourth layer, below an average depth of 18 or 20 inches, is loose loamy sand or sand containing small amounts of fine gravel. The color ranges from yellowish brown when dry to dark yellowish brown when wet. With depth the less weathered material becomes more varied in color and texture. Some coarse gravel and small stones are present. The soil material to a depth of 5 feet contains no free carbonates and is in many places acid in reaction. In this respect, as well as in showing a little stronger acidity in the surface layers, Nymore loamy sand differs from the Central soils. Nymore loamy sand occurs only in the region of Hubbard soils, whereas the Central soils are associated with the Wadena in the southern part of the county.

The dark-colored surface soil layer of Nymore loamy sand is its main feature of difference from the Menahga soils. Nymore loamy sand is transitional between the light-colored Menahga soils and the black soils of the Hubbard series in which the dark-colored surface layer ranges from 12 to 18 inches in thickness.

In section 3 of Blueberry Township and in small scattered spots elsewhere the surface soil is coarser textured than typical and the plowed surface soil is pebbly in places. The third layer here is heavier textured, approaching sandy clay loam, and is more coherent and sticky when wet, although it contains fine gravel and pebbles. Directly beneath the upper part of the porous sandy subsoil there is in places a thin layer in which coarse gravel and even small stones seem to be accumulated. The soil in many places grades into the Menahga soils so gradually that the boundaries between are in most places arbitrary.

The surface relief of Nymore loamy sand ranges from level or undulating to gently rolling. The areas are not dissected by natural drainage ways to any extent, and surface drainage is not well developed except in the more rolling areas. Owing to the fact that the subsoil and substratum are very permeable and that the surface soil is only moderately retentive of moisture, internal drainage is such as to make the soil somewhat droughty though the moisture-holding capacity is better than in the Menahga soils.

The native vegetation consists of jack pine and Norway pine, with popular, birch, northern bur oak, and red oak well represented. (Pl. 1, B.) The cover of Nymore loamy sand contrasts with that of Menahga loamy sand in diversity of species and in luxuriance of growth.

The parts of three northern townships in which the greater part of the Nymore loamy sand occurs are only moderately well settled, and although the individual farms have good-sized clearings and cultivable acreages the greater part of this soil (perhaps two-thirds) is in woodland or has been recently cut over. Farm improve-

ments are fair. The soil is managed much as is Menahga loamy sand.

Table 7 shows the results of mechanical analyses of samples of the surface soil, subsurface soil, and subsoil of Nymore loamy sand.

TABLE 7.—*Mechanical analysis of Nymore loamy sand*

No.	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
321925	Surface soil, 0 to 3 inches	6.8	18.9	16.3	18.1	5.6	23.7	10.8
321926	Subsurface soil, 3 to 9 inches	3.6	31.7	24.1	20.7	2.6	12.9	4.4
321927	Subsoil, 9 to 18 inches	2.2	27.0	24.6	26.6	3.5	9.8	6.5
321928	Subsoil, 18+ inches	5.3	34.5	25.8	29.9	1.7	1.6	1.6

MENAHGA LOAMY SAND

Menahga loamy sand has a thin surface layer of brown forest litter composed of pine needles and partly disintegrated leaves of deciduous trees and various shrubs, underlain by a 1 or 2 inch layer of very dark grayish-brown humous soil consisting of sand grains and disintegrated organic matter, intimately mixed. Below this is an 8-inch layer of light grayish-brown loamy sand becoming noticeably darker when wet. This material is single grained except for a few small soft aggregates. When moist it is only moderately coherent.

The next lower layer, about 10 inches in thickness, is brown loamy sand which when moist is moderately coherent and very slightly sticky and when dry breaks into friable angular fragments from one-fourth to 1 inch in diameter. The fifth layer, below a depth of 20 or 24 inches, is yellowish-brown or light-brown light loamy sand or sand. When wet the mass is very slightly coherent. With depth the sand becomes less weathered, grayer, and less coherent. It is composed chiefly of quartz grains, but fragments of other minerals constitute 5 or 10 per cent of the mass.

Although the soil is described in layers, the line of demarcation between the layers is faint except where a texture somewhat heavier than typical in the fourth layer more plainly sets it off from the others. The soil throughout is generally loose and permeable, although the fourth layer is in some places moderately retentive of moisture. The reaction is generally acid to a depth ranging from 3 to 5 feet. Small amounts of lime carbonate are present in places below these depths. The organic matter is almost entirely on the surface as leaf mold or litter. There is only a shallow layer of humous soil and faint dark streaks in the soil layers below. With clearing and cultivation this organic surface covering quickly disappears. The soil material throughout is free from bowlders or large stones, having been reworked, well assorted, and deposited by glacial waters.

In proximity to or in association with the Rockwood, Nymore, and Aldrich soils Menahga loamy sand in many places has a surface humous layer 3 or 4 inches thick. Other variations noted, especially in proximity to the Rockwood soils, are a fourth layer heavier than typical and an unweathered substratum like that of the Rockwood soils underlying the sand material of the Menahga soils at a depth

of 5 or 6 feet. Other areas show a distinct content of gravel, mostly fine gravel, intermixed with the sand in the layers below the third. The gravel is not confined to a definite layer but seems to be a part of a sandy outwash deposit more heterogeneous than typical. These more gravelly areas are loose and permeable though they seem to be somewhat more retentive of moisture than the typical soil. In only a few places is there a layer of distinctly heavier material, often having a slightly red cast, present in the gravelly areas. A plain of this gravelly phase, comprising 3 or 4 square miles, occurs along the northeast side of Redeye River in southwestern Meadow and northwestern North Germany Townships.

In association with the Sebeka soils Menahga loamy sand shows another variation worthy of mention. These areas show a higher water table than typical, and the soil layers below a depth ranging from 16 to 20 inches show the influence of a higher maintained moisture content. In the fifth layer the characteristic gray, rust-brown, and yellow stains of the Sebeka soils are present. Such areas are generally more level and occupy a little lower position than typical Menahga loamy sand. The better-maintained soil moisture is reflected in a thicker underbrush growth and a greater proportion of poplar and hardwoods among the jack pine timber. Boundaries between such areas of Menahga loamy sand and the Sebeka soils are arbitrarily established and in many places the two soils, together with areas of Newton soils, are so intermixed on low slightly undulating plains that only the soil type of greatest area could be shown on the map. In southern Shell River Township there are examples of this condition.

Menahga loamy sand occurs in the northern and central parts of the county. Areas are almost level or undulating, and surface drainage is not well developed. However, the permeable soil allows rapid internal drainage, causing the soil to be droughty. The present vegetation of the uncultivated areas is chiefly small or medium sized jack pine with some Norway pine, poplar, and small birch, with scattered scrub oak, hazel brush, and a sparse grass stand on the forest floor.

Menahga loamy sand is recognized as a droughty soil, and crop growth is usually retarded during the dry spells common to the normal growing season for this county. Less than one-fifth of the soil is in farms. The farms average about 130 acres in size, and buildings and improvements are only fair except on a few well-improved farmsteads.

The 20 or more sales of this soil during 1925 and 1926 involved some without building improvements and some with fair improvements. The indicated average market value is $20 an acre.

MENAHGA SAND

In typical Menahga sand the soil layers are only faintly differentiated. A thin surface layer of pine needles, moss, and other organic matter is underlain by a 1 or 2 inch layer of gray sand with a very small amount of organic matter in the upper part, and below this is a 10-inch layer of yellow or yellowish-brown loose sand. Except for a few very soft granules which shatter easily into a single-grained mass the material is single grained in structure. When

moist it is not at all or only very slightly coherent. It grades downward into more yellowish sand. Below a depth of 20 or 30 inches the soil material is grayish-yellow loose sand, mostly quartz but containing some feldspathic and ferromagnesian minerals. Slight or strong acidity is present in all layers above a depth ranging from 6 to 10 feet; below this depth the material is neutral or alkaline. No bowlders occur in or on the soil. The main difference between Menahga sand and Menahga loamy sand is the greater permeability and lack of definite heavier layer in the subsoil. Boundaries between the two soils are in most places very arbitrarily drawn.

Only a few minor variations occur in this soil. In the areas in proximity to the Kinghurst soils scattered small bowlders may be on the surface or the sandy drift substratum may lie at a depth of 6 or 7 feet. A small proportion of fine or medium sized gravel is scattered through the subsoil and substratum in places, especially in the areas in Blueberry and Shell River Townships. The areas having a higher water table than typical occur mainly in association with the peat and poorly drained areas in Meadow Township. Although the material of Menahga sand appears to be a little better assorted than that of Menahga loamy sand, there is the same range in the texture of the sand. In the sand soil, however, less very fine and fine sand and more medium and coarse sand are present than in the loamy sand soil. In a few places wind has probably deposited a covering of fine sand. Such areas are common in proximity to areas of Menahga loamy fine sand.

Menahga sand occupies ridges or undulations of slightly higher elevation than Menahga loamy sand, and thus run-off is a little greater and the soil is more droughty. A common occurrence of Menahga sand is on the slightly ridged parts of the outwash plain bordering lakes and peat bogs. Sandy ridges rising from lower poorly drained areas of the outwash plain or as "islands" in a peat bog are more common than in Menahga loamy sand. The ridges in such positions are not so excessively drained as typical, owing to the higher water table. The greater thriftiness of tree growth and vegetation on such areas reflects this difference in moisture conditions. The typical vegetation is a moderately dense stand of small jack pine, with a sparse ground cover consisting chiefly of heath plants. (Pl. 2, A.) Areas are mapped largely in the lake regions of Blueberry, Shell River, and Meadow Townships, in a strip bordering the Kinghurst soils in Orton and Lyons Townships, in Huntersville Township, and in northern Bullard Township.

About 15 per cent of the Menahga sand is in poorly improved, poorly stocked farms having comparatively small crop acreages. The limiting factors in crop production are the same as on Menahga loamy sand. Much of the soil has recently been cut over and is now covered with small pine or brush of little value. The market value of the land is considered a little lower than that of Menahga loamy sand.

MENAHGA LOAMY FINE SAND

Menahga loamy fine sand is similar to Menahga loamy sand except that there is a larger proportion of fine sand in the material of the

A, Profile of Rifle peat, showing the wood fragments in the upper layers; B, vegetation on burned-over bog of Rifle peat, showing roots and other tree remnants in the foreground

upper soil layers. The soil is loose and permeable throughout, but owing to the finer and somewhat more uniform texture of the sandy material it retains moisture a little longer than the other Menahga soils. The reaction ranges from slightly to strongly acid above a depth of 6 to 10 feet. No bowlders are on or in the soil. The vegetation is similar to that of the other Menahga soils but in most places is of thriftier appearance, reflecting a little better-maintained moisture conditions.

In sections 13 and 23 of Thomastown Township along Crow Wing River on high parts of the bottom land or on low adjoining terraces included areas show a browner color than typical in the second and third layers. In an area in section 9 of Thomastown Township the fourth layer shows the gray, rust-brown, and yellow colors typical of the Sebeka soils. Similar areas occur elsewhere between areas of Menahga loamy sand and the Sebeka soils. They support more hardwoods interspersed with the pine and a thrifty underbrush and grass growth.

Menahga loamy fine sand occupies higher ridges on well-drained plains bordering bogs or stream valleys and on lower ridges or gradual slopes from more prominent ridges of Kinghurst soils. The largest areas are in Wing River Township on the higher bluff ridges bordering Leaf and Redeye Rivers, and in section 1 of Huntersville Township, on a low elevated ridgy part of the outwash plain. The drainage is almost as excessive as on the other Menahga soils, and under cultivation the fine sand in the surface layer is subject to drifting more than the coarser-textured materials of those soils. This soil is of minor extent on any one farm. Its market value is about the same as of Menahga loamy sand.

MARQUETTE SANDY LOAM

In Marquette sandy loam a shallow covering of leaf mold and other organic matter is underlain by about a 6-inch layer of gray or grayish-brown loam or sandy loam, which when moist is coherent but mellow and friable. The next lower layer, which is about 5 inches thick, consists of clayey coarse sand and gravel, which is moderately loose and porous when dry and moderately coherent when wet. The color is variegated but the mass as a whole is brown when dry and dark brown when wet. The fourth layer, below a depth of 10 or 12 inches, is a loose incoherent mass of sand and gravel. The individual grains of sand and gravel are of varied color and lithologic composition, but the predominant color is grayish brown. The upper soil layers range in reaction from slightly acid to neutral. The sand and gravel of the substratum are alkaline, containing sufficient free lime to effervesce in dilute hydrochloric acid. Small stones (niggerheads) occur on the surface and embedded in the soil.

Marquette sandy loam is mapped on both rolling areas and level outwash plains. In many places the gravel has been excavated for use on roads. Deep cuts show the gravel to extend to a depth of 20 or more feet.

Very little of the Marquette sandy loam is cropped. As the topsoil is of moderate or good moisture-holding capacity, this soil

supports crops through dry periods better than the sandy soils of the Menahga series. However, the soil is used more as a source of gravel for road-building purposes than for agriculture. A large proportion of it is still wooded. On the rolling areas the timber is principally of the hardwood type, but white and Norway pines and oak are more numerous than on the Rockwood soils. On the sandy outwash plains the timber cover is oak and jack pine principally, with some aspen. The soil on these level plain positions has a topsoil of lighter color and sandier texture than the areas on the rolling uplands. Marquette sandy loam is considered of small value except where a workable gravel deposit enhances its value.

SEBEKA LOAMY SAND

The following soil layers comprise Sebeka loamy sand: (1) A thin covering of leaf and grass litter, roots, and humus; (2) about a 5-inch layer of grayish-brown loose porous loamy sand stained with gray, brown, rust brown, and orange, assuming a slight coherence and appearing very dark grayish brown when wet; (3) about a 30-inch layer of loose porous very light grayish-brown or light grayish-yellow loamy sand or sand stained with light gray, brown, orange, and rust brown and when wet appearing yellowish brown; and (4) below an average depth of 38 inches loose loamy fine sand or sand which, when dry, is mottled or variegated yellow, brownish yellow, gray, reddish brown, and orange. When moist or wet only a very slight coherence is noted. The water table is usually at a depth of about 4 feet. The soil shows varying degrees of acidity in all layers. It is derived from outwash materials characteristically free of bowlders.

The main included variations from typical Sebeka loamy sand occur in the better-drained more elevated parts of the areas approaching the level of the Menahga soils. Sebeka loamy sand in these positions does not show color stains in the surface soil layer and upper part of the layer below, resembling to this depth the Menahga soils. The vegetation contains more jack pine and less willow and alder brush than is typical on this soil. Considerable of the Sebeka loamy sand in sections 28, 29, 30, 31, 32, and 33 of Shell River Township and sections 21 and 22 of Meadow Township are of this character. Where the soil occurs in association with the Rockwood and Kinghurst soils the presence of scattered bowlders on the surface constitutes a variation. Such areas occur chiefly in Orton Township in association with Kinghurst loamy sand. In association with peat and the Newton soils Sebeka loamy sand in many places has a surface covering of mucky peat 4 inches thick. Much of the large area in sections 13, 14, and 23 of North Germany Township is of this character. A few small areas, such as the one in section 1 of Orton Township, appear to be in reality soils exposed beneath a burned-off peat covering. In this variation Sebeka loamy sand resembles the Newton soils in its surface covering of mucky peat but differs markedly from them in having more brownish and stained upper soil layers.

Sebeka loamy sand occupies flat or slightly depressed poorly drained areas generally intermediate in elevation between higher

better-drained soils such as the Menahga, Kinghurst, Aldrich, and Rockwood and more depressed areas of peat or Newton soils. Areas are in depressed flats or sloughs in outwash terraces, on slopes to depressions, slightly elevated islands in peat bogs, low benches or foot slopes below the higher ridges of the Rockwood or Kinghurst soils, and narrow marginal strips adjacent to peat bogs or peat drainage basins. The most characteristic natural vegetation is willow, alder, low birch, and aspen. Oak and jack pine are of scattered thin stands in most places. The grass and underbrush growth is luxuriant.

Only a very small acreage, mostly on the better-drained areas, of Sebeka loamy sand is cultivated. The greater part of the soil supports a good stand of grasses used for pasturage and wild hay. Some such meadows are of improved tame-hay grasses. The remainder of the soil is in woodland and brush, some of which affords pasturage. Only a few farms are composed in the main or wholly of this soil. From the sale of four such farms during 1925 and 1926 an average market value of $28 an acre was indicated. The less improved acreages are no doubt of less value.

SEBEKA SANDY LOAM

Sebeka sandy loam comprises areas in which either the surface layer or one or both of the two layers just below shows a sandy loam or heavier texture than obtains in Sebeka loamy sand. In all other respects it is identical to the loamy sand. Included variations are also similar to those described for the loamy sand.

Sebeka sandy loam occupies flat, poorly drained positions. The water table lies nearer the surface and the surface soil layers are more permanently moistened than in Sebeka loamy sand and below a depth of 3 feet the soil is water-logged. In vegetation, state of improvement, agricultural utilization, and adaptation Sebeka sandy loam is similar to Sebeka loamy sand. Small areas of that soil and of the Newton soils have been included in mapping.

BLUFFTON SILTY CLAY

Bluffton silty clay has a 4-inch surface covering of organic matter, underlain by about a 6-inch layer of black heavy silty clay which contains considerable organic matter and is in places rather mucky. When dry this layer is granular, the granules being hard; when wet it is moderately plastic and stiff. The next lower layer, which is about 4 inches thick, consists of very dark grayish-brown heavy clay loam which when wet is almost black. This layer contains more sand than the one above and is a little less plastic. The structure of the two layers is practically the same. The fourth layer is about 11 inches thick. It is heavy sandy clay loam or clay loam, not so stiffly plastic as the layers above when wet and a little more friable when dry, though the granules are hard. With depth through this layer the sand content increases. The predominant color when dry is light grayish yellow and when wet is dark grayish yellow, with mottles of gray, yellow, brown, rust brown, or reddish brown.

The fifth layer, which is about 20 inches thick, consists of heavy sandy loam of moderate plasticity and showing little or no stiffness.

When dry the structure is very finely granular, with the granules only moderately hard. A rather large part of the mass is of single-grained structure and of moderately friable consistence. In color it is similar to the layer above. This layer is underlain, below an average depth of 44 inches, by less-weathered materials showing little change from the layer above except a lighter-yellow or yellowish-brown color with a more distinctly gray cast. When wet this material is slightly sticky, with no stiffness and little plasticity. All the layers are alkaline in reaction. Pockets of grayish-white highly calcareous soil occur in the mottled layers. Bowlders are on the surface and variable amounts of embedded stone and gravel occur in the soil, especially in the lower layers.

Bluffton silty clay occupies poorly drained depressions in low sluggish drainage ways in the uplands, low foot slopes marginal to peat bogs, low flat terracelike levels below the uplands and marginal to streams, slightly elevated "islands" in peat bogs, and, in a few places, the floor of peat bogs where burning of the peat covering has exposed the mineral substratum. In association with the poorly drained phase of Rockwood loam, this soil commonly occurs on lower more poorly drained depressions. Areas of better drainage than typical are along Hay Creek in section 4 of Wing River Township and east of Sebeka. The last-named area also is more bowldery than typical. Ordinarily the bowlders are not numerous. The subsoil of Bluffton silty clay is commonly of variable texture, with sand and gravel layers or pockets. In a few areas, such as those in sections 21 and 28 of Red Eye Township marginal to shallow peat depressions and associated with the Rockwood soils, the subsoil of this soil is loose saturated sand and gravel. In places in Rockwood Township the subsoil is distinctly gray.

The natural drainage of Bluffton silty clay is poor. The surface is flat or depressed, allowing little run-off. The position of the soil is such that it receives slope waters from the surrounding higher levels. The heavy surface soil is slow in absorbing moisture, but water from rainfalls generally remains standing sufficiently long for the soil to become thoroughly wet; once moistened the topsoil gives up the moisture slowly to the more porous subsoil. The subsoil is saturated for considerable periods, owing more to the high position of the water table than to the high retentiveness of the material. Only in exceptionally dry periods or in seasons when such periods are timely is cropping of this soil practical under present drainage conditions, except on a few of the better-drained areas.

The natural vegetation on Bluffton silty clay is principally small aspen, alder, and willow brush, with some black ash, balsam fir, black spruce, and tamarack in places. The grass stand is heavy and luxuriant. On areas where a peat covering has been burned off, a thick tangle of coarse sedge grasses, reeds, cattails, and briers soon establishes itself. Considerable areas at present are in luxuriant grass meadows with only small clumps of alder and willow brush. These areas have been kept cleared of brush and the wild grasses given a chance to establish themselves. They afford excellent pasture or hay land. A ready catch and stand of alsike clover, redtop, bluegrass, and timothy mixtures makes the improvement of these lands as meadows easy. Under permanent pasturing the trampling of live-

stock creates a hummocky or tussocky surface which makes mowing for hay difficult.

In few if any places does Bluffton silty clay compose a great part of a single farm. The areas are maintained in permanent pasture or used for hay land. Better-drained areas are cropped and are very productive but rather hard to work. Crop yields are uncertain, particularly in wet seasons.

BLUFFTON SANDY LOAM

Bluffton sandy loam is similar to Bluffton silty clay in all essential respects except the texture of the surface 10 or 12 inch layer. This surface soil in most places is acid in reaction, whereas that of the silty clay is generally neutral or alkaline. The subsoils of both soils are calcareous.

Bluffton sandy loam occupies seepy upland slopes, depressions or incipient drainage ways, parts of slopes or low level areas marginal to peat bogs, and slopes below the levels of the Wadena soils in the southern part of the county. The areas associated with the Wadena soils are readily distinguished from the Granby soils by their bowldery surface. Natural drainage is poor because of the position of the soil in depressions or on seeped slopes where the subsoil is usually maintained in a saturated condition although the soil itself would allow rather thorough downward percolation of water. Some areas are better drained than typical and can be cropped satisfactorily except in wet seasons. Some of the slope areas in Aldrich Township are of this character.

This soil is less productive than Bluffton silty clay. The greater part of it is in pasture, some is in wild-hay meadow, and perhaps a fourth is in brush and timber. The grass cover is luxuriant. Under the trampling of livestock the sod of permanent pastures soon becomes hummocky or tussocky, particularly where the black surface soil is more or less mucky. Once trampled into this condition the improvement for use as hay meadows is more difficult. In some places use as hay land is not feasible because of the large number of bowlders on the surface.

GRANBY CLAY LOAM

Granby clay loam has a 2 or 3 inch surface covering of organic matter. Under this is about a 12-inch layer of very dark grayish-brown heavy loam or clay loam which when wet appears almost black. When dry the soil mass breaks readily into small particles and when wet it is soft and plastic. The next lower layer, which is about 6 inches thick, consists of dark grayish-brown loam or clay loam appearing somewhat darker when wet. Yellow and gray stains are present, as well as black or dark-brown organic stains streaked downward from the surface. When dry, the mass is more pronouncedly granular and the granules are a trifle larger and firmer than in the layer above. When wet it is coherent and moderately sticky. The fourth layer is about 10 inches thick. It consists of light sandy clay stained orange, gray, brown, and yellow. When wet, it assumes a dark olive-drab color and the stains are less pronounced. The structure is finely granular. The granules are hard when dry.

The fifth layer is about 16 inches thick and consists of loose sand containing variable quantities of fine gravel. When wet it is only slightly coherent. The material below an average depth of 48 inches is loose sand containing a small proportion of fine gravel. This layer is stained pale yellow and gray. When pulverized it is very light grayish yellow when dry and dark grayish yellow when moist. The dry soil mass is loose and incoherent but when moist is slightly coherent. This layer is very close to the average water-table level in the soil and is usually moist or saturated. It shows an alkaline reaction, and the layers above are neutral or only very slightly acid. This soil is derived from outwash materials free of bowlders and has developed under poor drainage conditions.

In variations from typical occurring on flood plains or low terraces the heavy textures extend to a depth of 3 or more feet. This deeper heavy-textured soil does not as a rule cover entire areas of this soil as mapped. In Red Eye and North Germany Townships the narrow back-bottom strips of the Redeye River flood plain and in Leaf River and Wing River Townships the broader areas on the flood plain of Leaf River show this variation. In the subsoil of a few small areas there is a high content of lime carbonate, often almost of the nature of marl. Such areas are in general heavy textured to a depth of 3 or more feet. An area of this kind is in section 15 of Thomastown Township on the south side of Partridge River on the flood plain of that stream. In places the marly material is 16 inches thick and lies at a depth ranging from 30 to 40 inches. Similar areas occur on the flood plains of Leaf, Redeye, and Crow Wing Rivers. Small areas resemble the Bluffton soils in the presence of bowlders on the surface but have the more uniform-textured sandy and fine gravelly subsoils of the Aldrich soils. Such an area occurs in section 36 of Red Eye Township on a low but distinct terrace level dissected by the channels of Redeye River.

Granby clay loam occupies flat and depressed positions in the outwash plain, distinct terrace benches only slightly elevated above adjacent first bottoms, and back-bottom positions on the wider flood plains. It is closely associated with the Wadena soils. Natural drainage is poor, surface drainage being restricted and internal drainage slow. The characteristic natural growth is similar to that on associated soils. The principal agricultural uses of Granby clay loam are for pasture and hay land. Some of the better-drained areas are cultivated very successfully in the longer growing seasons with well-distributed rainfall, and small fields are frequently put in short-season catch crops such as millet. The present market value of the soil hinges principally on its value as hay and pasture land.

GRANBY SANDY LOAM

Granby sandy loam has a black surface layer, a mottled poorly oxidized soil layer below, and a sandy or gravelly deep subsoil of alkaline reaction. The soil closely resembles Granby clay loam, except that the upper soil layers are lighter textured. Included with this soil as mapped are areas in which the texture of the surface soil ranges from heavy sandy loam to loamy sand. The texture of the upper part of the subsoil is typically no heavier than sandy

clay loam, and that of the lower part of the subsoil is sand and gravel, as in Granby clay loam.

This soil is associated chiefly with the Wadena soils in the southern part of the county, occupying depressed positions on the outwash terrace. Several scattered areas associated with the Menahga soils differ from typical in showing acidity to a greater depth and in having a thinner black surface layer. Such areas are to be found in sections 18, 19, and 20 of Bullard Township on a low poorly drained terrace between Redeye River and a large peat bog to the northeast, and in sections 23 and 26 of the same township on slightly elevated islands in peat bogs.

Natural drainage is generally poorly developed and the sandy or gravelly lower subsoil layer is moist or saturated. The vegetation on the soil is similar to that on Granby clay loam. Some fair-sized cultivated fields are maintained on the better-drained areas, the cultivated area being a little greater than on the clay loam of the series. Most of the soil, however, is in pasture and hay land and its market value is largely set by its value for those uses. It is the main soil on only a few farms, and current sales offer no index of its exact market value.

NEWTON SAND

Newton sand has a surface layer, ranging in thickness from 1 to 4 inches, consisting of organic matter in various stages of disintegration and decay. Below this is about a 4-inch layer of sand mixed with black organic matter. The third layer, which is about 4 inches thick, consists of very dark grayish-brown or dark-gray loose sand. When moist this material becomes moderately coherent. The next lower layer is about 10 inches thick. It consists of grayish-white loose sand mottled with darker gray and pale yellow, becoming dark grayish yellow and only slightly coherent when moist or wet. Below this is loose light grayish-yellow sand about 14 inches thick, becoming grayish brown when wet and having practically no coherence. Below an average depth of 44 inches is slightly coherent dark grayish-yellow or brown loose saturated or moist sand.

Newton sand shows varying degrees of acidity in all layers. No large rocks or bowlders occur on the surface or in the soil. In a few places the sand particles are coarse, with fine gravel and pebbles present in the various layers. The soil as a whole is of various grades of sand, averaging medium in size, intermixed in all layers.

Newton sand occupies low poorly drained depressions in the sandier outwash plains on which the Menahga soils are the most extensive. The water table is generally no deeper than 52 inches and is higher in some places.

The native vegetation is commonly a brush growth of willow, poplar, birch, and alder, with a good grass stand. In places, especially along the edges of the open grass bogs, it is entirely grass.

Newton sand occurs chiefly in association with peat, occupying marginal strips on the edges of bogs, slightly elevated islands in the bog, or depressed sloughs connecting two or more bogs. A few small areas occur in the depression occupied by Crow Wing River in Huntersville Township, chiefly in association with muck. A small

area of soil also occurs in a back-bottom position along Leaf River in Leaf River Township, in association with the Granby and Thomastown soils. A few areas, as the one in section 15 of Huntersville Township, are in the beds of former ponds or small lakes which have been artificially drained. In association with the Sebeka soils Newton sand occupies more poorly drained positions as a rule. Scattered bowlders are on the surface of a few areas marginal to peat areas and lying below areas of Kinghurst or Rockwood soils. Such is the case in section 26 of Orton Township.

Practically one-half of the Newton sand in this county is in open wild-hay meadows and pasture, and the remainder is in brush and small timber. Very little of the soil, except small tracts with better drainage than typical, is cultivated. In dry years these better-drained areas yield more than the Menahga soils, but in wet years, successful cropping is very uncertain.

The market value of Newton sand is considered about the same as that of Sebeka loamy sand.

NEWTON SANDY LOAM

Newton sandy loam is similiar to Newton sand but is heavier textured. The surface soil ranges from loamy sand to clay loam but is mainly sandy loam. The layer below the surface soil ranges from sandy loam to clay loam, and below an average depth of 12 or 16 inches the material is loose sand similar to the substratum of Newton sand. The peaty sand surface covering typical of Newton sand is in this soil commonly a mucky sand.

Newton sandy loam occurs in positions similar to those occupied by Newton sand. Natural drainage is poor, and the soil is a little more slowly penetrable than Newton sand because of the heavier texture of the upper soil layers. The natural vegetation is of the same character as that on the sand of the series but in most places is of slightly thriftier growth, both in the brush and grass stand. Still smaller tracts of the sandy loam than of the sand are cultivated. These cultivated tracts are the few on which natural drainage conditions are better than typical. The principal use of the soil is for pasture and hay land, and its value is more or less fixed by such utilization.

THOMASTOWN LOAMY SAND

Thomastown loamy sand has a thin surface covering of leaf mold and other organic matter, underlain by a layer of loamy sand which when dry is very dark grayish brown and of very fragile and very finely granular structure, the granules readily breaking up into the ultimate texture particles, and when wet is deep chocolate brown and moderately coherent. This is underlain by a layer about 12 inches thick of loamy very dark-brown sand which when wet is chocolate brown. This material is very fine and more granular in structure than the layer above, and the granules are less fragile. When wet this layer is more strongly coherent than that above it. Below this is a layer of very dark-brown loamy sand about 12 inches thick, which when wet appears darker brown. The structure masses formed

in the dry material are hard to shatter into their single-grained component parts. When wet the layer is fairly coherent.

Below an average depth of 40 inches the soil materials differ from place to place. In a few places the substratum is gravelly, in others is loose sand, and in still others is sandy loam. These various kinds of substratum are not considered a part of the Thomastown soil material. The Thomastown soil seems to be derived from a comparatively thin mantle of more recently deposited, more uniformly assorted soil materials than those from which the older more weathered Menahga and Wadena soils are derived. The occurrence of the Thomastown soil on low terrace positions only slightly elevated above and usually adjacent to present flood plains indicates that this uniform-textured soil is more of true stream-terrace than of glacial-outwash materials.

Thomastown loamy sand contains no gravel and coarse sand intermixed in the soil, save that occurring in the deeper substratum. The soil ranges from slightly acid to slightly alkaline, in few places showing strong degrees of acidity or of alkalinity.

Distinction between Thomastown loamy sand and Wadena loamy sand is difficult where the Wadena soil has a more uniform texture profile and a lighter-colored surface soil than typical. Compared to Wadena loamy sand Thomastown loamy sand, even in such places, commonly has a more brownish surface soil.

The main variations in Thomastown loamy sand are a texture profile of a loamy fine sand soil, a subsoil of loose sand or fine sand at a depth of about 2 feet, an 8 or 10 inch surface soil which is almost black when wet, and areas of Thomastown sand too few and small to separate.

The largest individual areas of this soil are on the large bends of river courses. Areas are numerous on the Leaf River flood plain.

Its natural drainage renders this soil well suited to cropping except in the drier seasons. The level surface allows the greater part of the rainfall to be absorbed and percolate downward through the soil. This percolation is rather rapid, and drainage would be excessive but for the fact that the low position of the soil gives it a water table sufficiently near the surface to keep the subsoil in good moisture condition.

The natural vegetation on Thomastown loamy sand is principally aspen, with elm, ash, maple, balsam poplar, oak, and other hardwoods represented. Mixed with this hardwood growth are jack pine, Norway pine, white pine, balsam fir, and spruce. In a few places the jack pine predominates in the cover. The timber growth is thick and there is a dense underbrush and grass growth. The areas on the Leaf River flood plain in Leaf River and Wing River Townships, comprising about one-half the acreage mapped, are largely cultivated. Elsewhere the cultivated plots are small and are in woodland pasture. The soil is productive and suited to practically all the common crops of the region. A few of the areas on the flood plains of Crow Wing River are flooded for short periods during occasional seasons. Those areas along Leaf River are seldom if ever damaged.

This soil does not compose the whole of any one farm and there are no sales which give an indication of its market value.

THOMASTOWN FINE SANDY LOAM

Thomastown fine sandy loam has a thin covering of leaf mold and other organic matter, below which is a layer of fine sandy loam about 11 inches thick which is very dark brown when dry and deep chocolate brown when wet. The soil is very finely granular in structure, the granules being slightly hard. When wet the mass is coherent and friable. This is underlain by dark-brown heavy fine sandy loam about 8 inches thick which is very dark brown when wet. This layer is a trifle more granular than the one above and the granules are slightly better cemented and are moderately hard. When wet the mass is coherent and slightly sticky. Below this layer is loose loamy fine sand about 12 inches thick which is dark brown when dry and chocolate brown when wet. The mass is very finely granular, the granules shattering into single grains with moderate pressure. When wet it is moderately coherent. Below an average depth of 40 inches is the substratum of less uniform texture than the soil above, consisting in different places of sand, gravel, or loam. To a depth of 40 inches the soil is free of stone, gravel, and coarse sand. Its reaction varies, but in few places is it strongly acid or strongly alkaline.

Thomastown fine sandy loam occupies positions similar to those occupied by Thomastown loamy sand. Included variations have darker-colored and less uniform surface soils, a texture profile resembling that of Wadena sandy loam; dark-brown surface soils shallower than typical and third layers of heavier texture, resembling the Nymore and Aldrich soils; and black surface soils 14 inches thick and deep somewhat mottled subsoils, resembling fine-textured Granby soil. Other variations have only very minor textural differences.

Thomastown fine sandy loam has moderately well-regulated internal drainage. Rain is readily absorbed and excessive amounts are retained only during wet periods. Owing to the reasonably high water table the subsoil usually retains sufficient moisture for crops during dry spells. The rates at which moisture is absorbed and given up by this soil are a little slower than in Thomastown loamy sand. Flooding by high waters is of only occasional occurrence.

About one-fourth of this soil is cultivated; the greater part is in woodland pasture. The timber is principally hardwood, with scattered pines on a few areas. Under cultivation the soil is well suited to practically all crops grown in the county and is recognized as being productive. No large areas compose an entire farm.

GRIFFIN SILTY CLAY LOAM

The surface soil of Griffin silty clay loam consists of a 3-inch covering of leaf mold, grass mat, and other organic matter. Below this is a 10-inch layer of very dark-brown or very dark grayish-brown very finely granular heavy clay in which the granules are hard and tough. When wet this material is plastic and slightly sticky. It is underlain by a layer, about 20 inches thick, of loamy fine sand, which is grayish chocolate brown when dry and very dark brown when wet. Stains of yellow, brown, rust brown, orange, and gray are numerous. The material is moderately coherent when wet and is rather loose and permeable when dry. Below an average

depth of 34 inches is looser loamy fine sand or sand becoming more variable in texture with depth. The color ranges from light grayish brown when dry to dark yellowish brown when wet, varied by stains of yellow, brown, gray, and grayish white.

Griffin silty clay resembles the Thomastown soils in being practically free of gravel and pebbles, in averaging neutral in reaction, and in occupying positions on low terraces or slightly elevated flood plains. Over the areas as mapped the clay loam surface soil is of variable thickness and in places ranges to fine sandy loam in texture. Thin layers of sandy loam, loam, and clay loam occur in many places in the loose porous subsoils. In some poorly drained places the clay loam surface soil is stained as in the Sebeka soils, but the main color of the soil is darker brown. In other low areas the soil is similar to Granby clay loam but has a more brown than black surface soil.

Griffin silty clay loam occurs in section 34 of Bullard Township and in other small areas on the flood plains of Leaf and Crow Wing Rivers in Thomastown and Leaf River Townships. Natural drainage ranges from good to rather poor. Surface drainage is fair or poor in slightly depressed areas. The heavy-textured surface soil is slowly penetrable and hinders internal drainage.

On the small part of the soil in timber there are thick stands of aspen, balsam poplar, spruce, and balsam fir, with a heavy underbrush and grass cover. The greater part of the soil is in pasture, but a few tracts are cultivated. Under cultivation Griffin silty clay loam tends to be slightly intractable. Cropping practices and yields are very similar to those on Thomastown fine sandy loam.

ALLUVIAL SOILS (UNDIFFERENTIATED)

On the flood plains of the larger streams of the county are areas of very mixed alluvial soils classed as alluvial soils (undifferentiated). Mineral soils ranging from heavy black silty clay loam to clean river-wash sand with and without surface coverings of peat or muck and areas of peat and muck and of Thomastown, Newton, Sebeka, and Granby soils too small to map separately make up these mixed lands. Along Hay Creek in Rockwood and North Germany Townships the areas are largely shallow peat. Along Redeye River in Meadow and Rockwood Townships, Leaf River in Leaf River and Wing River Townships, and Wing River and Union Creek in Wadena Township these areas are more mucky. Many of the mucky areas in Leaf River Township showed a sandy subsoil resembling that of the Sebeka or Granby soils. In the narrow bottoms in Blueberry Township the channels are bordered by narrow strips of river-wash sand with back bottoms of muck, shallow peat, and Newton soils. Along Partridge River in Aldrich Township there are similar strips of sand, and the principal soil of the back bottoms is deep black silty clay loam, including small mucky spots. The areas along Leaf River in Bullard and Thomastown Townships and along the Crow Wing River in the latter township are higher and better drained. They include ridges of sand or a soil resembling the Thomastown soils, with a network of narrow dissecting overflow channels. Little or no peat and muck occurs on these areas, the flatter parts being principally heavy black

silty clay loam slightly mucky in places. On this kind of bottom land there is a moderately dense growth of various hardwoods and a pasture-grass sod of fine quality. The more poorly drained bottoms consist mainly of hummocky more or less brushy grass meadow in many places densely covered with bushy growth. On such bottom lands tree growth is less common and where present is less thrifty, but the underbrush is very dense.

The undifferentiated alluvial soils are devoted solely to pasture and hay meadows, except in a few small patches on the higher lands of the Leaf and Crow Wing River bottoms.

ORGANIC SOILS (PEAT AND MUCK)

The organic soils are composed mainly of plant remains and in this respect constitute a distinct class in comparison with soils which are composed principally of mineral or inorganic matter. In this region the organic deposits have accumulated in permanently wet situations such as swales and flat valley floors, slopes permanently wet from seepage water, and certain kinds of lakes, some of which have been completely filled by plant remains. The organic deposits from which these soils have been derived range in thickness from 1 foot to 15 or more feet. Organic soils differ in the nature of the mineral substrata (whether marl, sand, or clay), in the average depth to the water table, in the botanical composition of the plant remains, in the age and stage of decomposition of the plant matter, in the ash content, and in the quantity of mixed foreign mineral material present. The organic soils comprise nearly one-fifth of the total area of the county.

Several types of peat might be differentiated on the basis of the differences noted, but owing to the difficulties and cost of consistently making such distinctions in soil mapping and to the present low value of the organic soils, only three types, Badoura peat, Rifle peat, and muck, were separated. A further phase separation on the basis of thickness of the deposit was made in the case of the two peat types, deposits 2 or more feet thick being mapped as deep or typical peat and less than 2 feet thick as a shallow phase.

The two types of peat mapped are distinguished on the basis of physical characteristics of color, texture, structure, and readily observed differences in botanical composition of the plant remains. Badoura peat is made up largely of remains from grasses, sedges, and other nonwoody vegetation; Rifle peat is composed in part of woody remains of trees. In a field classification chemical composition was not and could not be directly used as a criterion for distinguishing between kinds of peat. Therefore the distinction, as shown on the soil map, does not directly indicate any particular chemical characteristics, such as calcium content.

The two types of peat in their more typical development are clearly distinct and well defined. However, over much of the county, the peat has characteristics intermediate between the two types, boundaries are gradational, and differentiation on the soil map is only approximate. Over some of the area, the criterion used in mapping was the native vegetation, the timbered areas being mapped

as Rifle peat and the grassland areas as Badoura peat. Although some corrections were subsequently made in revision, there is no doubt that considerable areas shown as Badoura peat, at present without timber, have the soil profile characteristics of Rifle peat.

Badoura peat.—Badoura peat, which includes the organic soil deposits typical in the open grass bogs of the northeastern part of the county, has a 3 or 4 inch surface layer of dead grass and grass roots. Below is an 8-inch layer of brown or dark-brown fibrous peat in which grass roots are conspicuous. When dry, the material cakes into rather brittle masses. Between depths of 8 inches and 3 or 4 feet (the depth to the water table) there is fibrous peat more compacted than at the surface. This breaks into masses of horizontal cleavage with smooth somewhat glistening and blackened cleavage faces. These platy-structured masses when broken vertically expose a brown fibrous surface showing the plant remains packed in horizontal arrangement. Below the water table the peat is waterlogged and generally loose and soft. (Pl. 2, B.)

Included with Badoura peat are open boglands where water remains on the surface permanently or through the greater part of the season. Such areas occur adjacent to lakes, in beds of dried-up lakes, or along the smaller streams and consist largely or entirely of remains of aquatic plants. They are almost continuously waterlogged. In other areas mapped as Badoura peat the material is made up in part of disintegrated wood, such as is more typical of Rifle peat. These areas of Badoura peat are at present largely or entirely open grass bogs, the timber having been destroyed partly by cutting and partly by fire.

Badoura peat occupies broad flats and valleys in the rolling uplands and on the plains, lowlands marginal to existing lakes and ponds, back bottoms of the larger flood plains or the entire flood plain where the stream has not as yet deposited alluvium, and some of the seepy slopes adjacent to and above all such depressed lowlands. Only a few of the peat areas are entirely hemmed in and separated from natural drainage outlets. They commonly are connected with each other and with the streams by narrow sloughs, which are entirely inadequate to provide any marked run-off except when water levels of the peat bogs are highest. Most of the small swampy areas where standing water remains permanently or through the greater part of the season occur adjacent to lakes or in the beds of lakes such as Mud and Rice Lakes in Meadow Township, which are inadequately drained by single outlet ditches.

The present vegetation on Badoura peat consists of sedge, wire grass, and other grasses. (Pl. 2, C.) Wire grass for use in the carpet industry has been cut from several of the bogs in recent years.

Badoura peat, shallow phase.—The shallow phase of Badoura peat resembles typical Badoura peat, but the layer of peat is 2 feet or less thick and the underlying mineral substratum is variable. In most places a thin surface layer is of finely divided peat, approaching muck in stage of decomposition, and in many places the 6-inch surface layer is black peaty muck. The peat material of the shallow phase, except in the layers just referred to, is but little better decomposed than that of Badoura peat.

Badoura peat, shallow phase, occupies marginal strips on the edge of the deeper peat bogs or along sluggish natural stream ways traversing them, the narrower upland valleys, and positions on the flood plains similar to those occupied by typical Badoura peat. Natural drainage is not quite so restricted as in typical Badoura peat, but artificial drainage improvements are required for maintenance of the best moisture conditions for cropping. This shallow peat is mostly in wild hay and pasture land. On several large areas moderately dense growths of willow brush with some alder occur in association with open grassy meadows.

Shallow Badoura peat does not comprise any great part of single farms and is not cropped except in small acreages where the peat is sufficiently shallow to allow incorporation of the mineral soil with the plowed surface. Farmers declare such areas to be more productive than the sand soils. The market value of shallow peat is a little higher than that of deep peat.

Rifle peat.—Areas mapped as Rifle peat include the peat bogs covered by timber or containing conspicuous stumps and wood fragments and having woody upper layers. (Pl. 3, A.) The 4-inch surface layer consists of moss and forest litter. This is underlain by an 8-inch layer of loose and mellow dark-brown coarse woody peat composed of coarse root and wood fragments mixed with finely divided fairly well-decomposed vegetable remains. Below this is a layer, about 22 inches thick, of less decomposed lighter-brown peat, more firmly packed but without distinct lines of cleavage. The coarse woody fragments are smaller than in the surface layer and are more hidden and packed within a brown fibrous mass. This layer is underlain by about a 10-inch layer of compact brown fibrous peat of platy structure, similar to the third layer of Badoura peat and apparently consisting of sedge and aquatic plant remains. Below an average depth of 40 inches the ground water usually makes the peat loose and soft.

The depth of the peat in many places is 8 or 10 feet and in small spots in some areas is greater; considerable areas are little more than 3 feet deep and the estimated average depth is about 5 feet.

The natural vegetation on Rifle peat is or was principally tamarack, black spruce, balsam fir, aspen, birch, balsam poplar, and black ash. On some of the drier burned-over bogs there is a thick solid stand of small aspen. (Pl. 3, B.) Alder and willow brush form the underbrush. A scattered growth of sedge and some grass, a scattering of mosses, leatherleaf (Cassandra), Labrador-tea, raspberries, cranberries, and blueberries in places cover the bog floor. A large total area of the Rifle peat has been cleared for hay and pasture land, and a good growth of wild grasses has become established. This is practically the only agricultural use to which this land is put at the present time. Its present market value depends on its value as hay and pasture land.

Rifle peat, shallow phase.—The shallow phase of Rifle peat includes areas of woody peat in which the mineral substratum lies at a depth of less than 2 feet. The natural vegetation on such areas is more dominantly hardwood and balsam fir, with less tamarack and black spruce. This phase is of minor importance in Wadena County.

Muck.—Muck consists of a mass of black decomposed plant remains intermixed with mineral soil particles, mainly of the finer textures. It is light in weight and somewhat spongy. When wet it assumed a moderate degree of plasticity and when dry becomes granular with a tendency to crack on further drying. This material ranges in thickness from 1 to 3 feet. In most areas the materials below a depth of 1 foot are varied, in some areas being peatlike, in others loose sand, and in others heavy silty clay loam or mucky silty clay. Where the muck is only 1 foot deep over a subsoil typical of the Granby or Newton soils the area has been classified with those soils. In most places, however, the subsoils below a 1-foot covering of muck are so mixed in color, texture, and physical appearance that they do not conform to any one soil series. The areas on the flood plains of streams are most mixed. The areas occupying back-bottom positions on a flood plain are typical, as are also the areas in Leaf River Township and Red Eye Township in the bottoms of Leaf and Redeye Rivers. An area in the Crow Wing River bottoms in Huntersville Township is underlain by marl. Where the muck is marginal to a peat bog, the underlying material is usually mixed peat and sand; in association with the Granby soils in depressions on the terrace plains it is a mixture of sand, sandy clay, clayey gravel, or mucky silty clay.

The areas of muck on flood plains are too wet for cropping, and it is impractical to improve them for such use. Areas in the depressions of terrace plains respond well to drainage improvements. In association with peat bogs muck is more difficult to improve.

The muck areas on the flood plains support a thick growth of high bushes, such as willow, alder, and small aspen. In many places a dense hardwood growth of aspen, balsam poplar, ash, elm, and maple is on these areas. A luxuriant growth of coarse grass has become established, particularly in the openings in the brush or timber cover. Few of the areas occupying back-bottom positions support a timber growth though they may be brushy and many are covered by a hummocky or tussocky grass meadow. The greater part of the muck is in pasture or hay meadows. Very little cropping is done. The market value is considered a little higher than that of the shallow phases of peat.

MANAGEMENT OF WADENA COUNTY SOILS

From observations made during the progress of the survey and information obtained from farmers on the different kinds of soils a few of the more generally recognized facts regarding the productiveness and adaptability of the various soils to cropping can be stated. Discussing the soils from this viewpoint the various soil types can well be grouped according to similarity of drainage conditions and natural fertility.

In one group are Rockwood loam and sandy loam soils. In these soils natural fertility and favorable drainage are combined to a greater degree than in any other soils in the county. The land is resistant to drought but is seldom too wet for good crop growth. These soils are well suited to all crops grown in the county, particularly to clover.

Spring plantings can be made on Rockwood loam in time to mature a crop, but not so early as on the sandier soils of the county. Neither can the soil be worked under so wide a range of moisture conditions, so easily kept free from weeds, nor so readily maintained in a mulched condition in cultivated fields. Embedded stones and bowlders which are slowly but constantly emerging make cultivation a little more difficult than on the stone-free soils.

In a second group of soils are Wadena, Hubbard, and Central sandy loams, and Thomastown fine sandy loam. These soils have a greater content of organic matter than the productive Rockwood soils (except possibly Central sandy loam), but their water-holding capacity is not so great and their resistance to drought is less. For that reason crop yields on them are less certain, particularly of crops more susceptible to drought, such as red clover. Clean cultivation is easier on these soils than on Rockwood loam, owing to the fact that they can be worked under a wider range of moisture conditions and are free of stone and bowlders. Plantings can be made a little earlier than on the Rockwood soils, making maturity more certain, and for this reason a greater acreage is planted to corn. The more continuous cropping of these soils to corn and small grains tends to deplete their fertility, and the renewal of the nitrogen supply is made difficult by the uncertainty of maintaining clover stands. Where red clover proves difficult to grow, alfalfa and sweetclover, which have even greater soil-improving qualities, may be substituted. A good start has already been made in growing these crops in Wadena County.

These sandy loam soils produce potatoes of excellent quality, and in some years a considerable acreage is grown. Manure is not ordinarily applied in sufficient quantities to maintain the fertility, particularly when crop rotation to legumes is not practiced. Lime, phosphate, and commercial mixed fertilizers are not generally used. Central sandy loam and Hubbard sandy loam are more acid than the Wadena soils to a depth of 3 feet.

In another group closely allied to the group just discussed are Wadena, Thomastown, and Central loamy sands. These soils are not so resistant to drought as the sandy loam soils and are a little less fertile, owing to their smaller organic-matter content. Profitable crop yields are less certain than on the sandy loams but are not nearly so uncertain as on the soils of the Nymore group. The farmer on these soils may maintain soil fertility by the practices recommended for the Menahga and Nymore soils.

In another group can be placed the Menahga and Nymore soils which are very droughty and low in nitrogen. Nymore loamy sand with its shallow surface soil contains a rather small but still appreciable amount of organic matter and is of greater natural fertility than Menahga loamy sand. Under a few years' cropping, however, this difference in the fertility of the two soils is usually reduced, and the management required is the same. Successful cropping requires manuring, plowing under of crop residues and green-manure crops, or use of commercial fertilizers. The amount of manure produced on the farms is entirely inadequate for satisfactory cropping except on a small part of the farm acreage. Increasing the number of livestock on these farms with a view to producing greater quantities

of manure can be carried out only slowly, as the farm is made to produce a greater bulk of feed crops. Development of marl deposits may result in a more economical supply of lime.

Sweetclover seems the most promising soil-improving and green-manure crop, but very little is raised at present. Red clover at present is more widely grown than alfalfa and sweetclover, but results are discouraging because of its susceptibility to drought. In years of high market prices, the seed production from a stand of red clover too thin for use as hay or forage is a source of cash income. Of the small grains, rye is the best adapted to these soils, as it matures before damage from drought seriously affects it. Although planting of the spring-seeded small grains can be made earlier on these soils than on the Wadena and Rockwood soils, yields are very uncertain, even with the earlier varieties. Corn makes a small stalk growth, but in favorable seasons gives fair yields of grain; in dry seasons yields are very poor. Potatoes yield poorly except in seasons of plentiful rainfall, when satisfactory yields of good-quality tubers are obtained with proper fertilization. The dairy type of farming seems best suited to these soils. One of the hardest problems of the farmer is to produce sufficient forage to make the keeping of livestock profitable. Root forage crops such as rutabagas, stock carrots, and mangels are adapted to these soils and are important supplementary feed crops which can be relied on particularly in dry seasons. Poultry, bees, small fruits such as blueberries and strawberries, and garden truck offer supplementary farm income.

Still another group of soils includes the Kinghurst and Aldrich loamy sands, Marquette sandy loam, and Rockwood loamy sand. The limiting factors of these soils are similar to those of the Menahga soil group just discussed, but crop production is not so limited by these factors. Rockwood loamy sand and the Marquette and Aldrich soils are not so lacking in organic matter as the Menahga. Percolation through the surface soil is arrested by the heavier, less penetrable substratum common to all the soils of this group except the Marquette, and even this soil is rendered fairly retentive of moisture by the two heavier soil layers at the surface. Though these soils are not quite so droughty as the Menahga, the difference in this respect is not sufficient to make much difference in crop adaptation and management as regards cropping, fertilizing, and practices for conserving moisture. Average yields of the various crops are less uncertain than on the Menahga soils, and successful farming is not quite so difficult a task.

Considerable acreages of the loamy sand soils are in timber, but farmers state that opportunities for deriving income from timberlands are fast disappearing. Jack pine is the main timber growth on these lands. The timber of more merchantable quality, such as Norway and white pine, is very scattered. The growth of jack pine seems at present to be the soundest economic use for considerable areas of this kind of land.[3]

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[3] Detailed information regarding reforestation, forest preservation, and forest utilization can be found in the following bulletins: HANSEN, T. S. SECOND GROWTH ON CUT-OVER LANDS IN ST. LOUIS COUNTY. Minn. Agr. Expt. Sta. Bul. 203, 50 p., illus. 1923.
STERRETT, W. D. JACK PINE. U. S. Dept. Agr. Bul. 820, 47 p., illus. 1920.

The poorly drained mineral soils of the county can be classed in two rather distinct groups, the heavier-textured group and the sandy group. Common to both of these is the poor or imperfect drainage which even in the better-drained areas limits their successful cultivation to the drier seasons. Successful cropping is further limited by the greater frequency and liability of frost damage. Frosts frequently damage the crops on lands in the lower depressed positions and leave the crops on the well-drained locations untouched.

The most practical and feasible and almost the universal use for these soils is as pasture land and hay meadows. In many places where drainage is not too poor the meadows could be improved by seeding to tame grasses such as alsike clover, red clover, timothy, and redtop. Drainage improvement is even more necessary for tilled crops, such as corn, potatoes, and small grain than for meadows. Such improvement of the lands is only practical where the soils involved are potentially productive when drained.

Under cultivation the heavier-textured soils including the Bluffton and Granby soils require management a little different from that given the more sandy soils like the Newton and Sebeka. The heavier-textured soils can not be planted so early as the sandy soils, and the crop is ranker in growth and later in maturing. Small grains are often damaged by lodging and rust. Corn produces excellent stalk growth for fodder or silage, and in favorable seasons a good grain crop is matured. A well-matured grain crop is more uncertain than on the Wadena soils. In dry seasons the crops on the Bluffton and Granby soils are not much damaged by drought. The high organic-matter content of these soils contributes to a high state of fertility, which is reflected in the rank growth.

Potatoes on the heavier-textured soils produce well when the season is not too wet, but the tubers are said to be of coarser, less firm texture and poorer quality than those produced on Wadena sandy loam and similar soils. The successful cropping of these soils hinges largely on maintaining them in a well-drained and tractable condition. Crop residues and moderate amounts of manures plowed under help to mellow the seed bed. The tame-hay grasses and legumes are best suited to these soils. Alfalfa requires more thorough drainage than the clovers and timothy. Unless the seed bed is put in good tilth and cleanly cultivated, the tame-hay stands may be subject to slight damage from drought or from heaving during the winter, or from infestation and choking out by June grass and other wild grasses. As pasture the tame-grass meadows are far superior to the permanent wild-grass meadows, not only because of the greater nutritious value of the grasses but also because of the firmer, denser, and more uniform sod of tame grasses which resist damage from the trampling of livestock so noticeable on the wild-grass pastures. These heavier-textured soils support grass stands throughout the summer, whereas on practically all other soils the pasturage is greatly diminished during dry periods.

There is little evidence that these soils need lime. The Bluffton soils as a rule are not acid, even in their surface soils. Granby sandy loam is in places slightly acid to a depth of 18 or 20 inches. The subsoils and substrata of the Granby soils have a lime content

similar to that of the Wadena soils, and certain areas have highly concentrated lime in the subsoil.

The sandy poorly drained soils of the Newton and Sebeka series are not so rich in organic matter as the Bluffton and Granby soils and have less natural productiveness. This is particularly true of the Sebeka soils, which have fertilizer needs similar to the Menahga soils. The mucky surface covering of the Newton soils makes them slightly more fertile, but after a few years of cropping their fertilizer needs are also similar to those of the Menahga soils. The sandy porous subsoils of the Sebeka soils render them droughty in dry periods and their poorly drained position makes them subject to damage from a high water table in wet periods. Drainage improvement for cultivation, unless means be provided for maintaining the water table at a proper depth, further increases their droughtiness. This fact, together with their lower fertility, makes their improvement for cultivation less feasible and their promise of satisfactory crop yields less certain than in the heavier-textured soils. In their present state the Newton and Sebeka soils support a good stand of wild pasture and hay grasses, but the stands are not so well maintained during dry seasons as on the heavier-textured soils. Because of this tendency to drought alsike clover and redtop are more suited for tame-hay meadows than red clover.

The organic soils, peat and muck, seem at present to have a more restricted agricultural utilization than any other soils in the county. Poor drainage, very low natural productivity, and great susceptibility to frost damage limit the use of these soils for agriculture. Considerable effort has been expended on their drainage in most places with the mistaken idea that drainage alone was required to make them productive. Most of the 250 miles of drainage ditches operating in the county traverse peat areas; in many places considerably more work must be done before the areas can be utilized for agriculture.

Peat soils are so different from mineral soils that usually one inexperienced in handling them should begin farming on them on only a small scale. Peat soils all need drainage and with rare exceptions need liberal fertilization. On some, liming also is indispensable for the production of ordinary farm crops. Liability of sensitive plants like potatoes to injury or destruction from summer frosts is another disadvantage.

If peat land be well drained, well prepared, and seeded without applications of fertilizer, the crops are usually a complete failure. Stable manure, when used in required quantities, is sufficient fertilizer for peats known as high-lime peats, which are rich in lime. However, unless the manure is exceptionally plentiful, it is more profitable to use it on mineral soils and to apply commercial fertilizers on the peat, as the nitrogen in the manure, although the most valuable constituent on most mineral soils, is of little or no benefit to high-lime peat soils because of the natural richness of these soils in available nitrogen. Most of the high-lime peats need fertilization with both phosphate and potash, although some require only phosphate and some only potash.

Summer frosts, characteristic on peat soils, are so common that they form the most serious handicap to the utilization of such

lands, except for crops such as grasses, common clovers, and hardy vegetables, which are almost proof against frost injury. On an experimental field of peat in north-central Minnesota there was frost on 18 different nights in one season, but corn on sandy loam soil only 100 yards from the edge of the peat was not injured.

Wherever the water table can be lowered a few feet below the surface, excellent meadows and pastures of tame grasses and clovers can be established by the use of the proper fertilizers, with or without lime as required. Hardy vegetables such as carrots, cabbage, and turnips withstand the summer frosts and yield well. Under favorable conditions high yields of potatoes of excellent quality can be obtained, but summer frosts may be expected so frequently in Wadena County as to make potatoes a very uncertain crop.

Farmers who have not yet drained peat areas on their farms are advised, before going to the expense of drainage, to find out whether the areas are of high or low lime content.[4] They should also proceed cautiously with drainage, as this may prove so expensive that the reclamation of the peat will prove unprofitable even where the best modern methods are used.

Brief mention has been made of marl deposits in the county as a source of agricultural lime. These deposits generally occur beneath the muck and peat, to a smaller extent beneath the poorly drained soils of the Bluffton and Granby series, and to some extent beneath the alluvial soils. The areas of their occurrence are small and scattered but are a source of lime for practically every farming neighborhood in the county. One of the larger areas is in the Crow Wing River bottoms in the northwestern corner of Huntersville Township.

SUMMARY

Wadena County is a little northwest of the geographic center of Minnesota. Its land area is 342,400 acres.

The surface relief of the county is of two distinct types. The greatest area is a level undulating plain. A gently rolling relief occurs over a smaller part of the county, in the west-central and east-central parts. There are no marked elevated areas, hills, or ridges. The average elevation is about 1,350 feet above sea level. There are few lakes but numerous poorly drained depressions.

The lands of the county lie entirely in the watershed of Crow Wing River. Tributary drainage ways are only moderately well distributed over the county, and considerable areas are inadequately served by natural outlets. The level plain surfaces, aside from the depressions, are well drained because of the porosity of the substrata. The slopes effectively drain the gently rolling ridge lands and contribute to the poor drainage of the depressed areas.

The main types of timber cover in the county are the jack pine stands on the sandy soils, the mixed hardwood and conifer timber on the heavier soils, and the stands of tamarack, black spruce, and other water-loving vegetation on the peat lands.

[4] More detailed information regarding the management of peat soils in Wadena County may be obtained from the division of soils, Agricultural Experiment Station, St. Paul, Minn. Samples of peat for examination as to lime content may be sent to the same address, from which may be obtained directions for taking the samples properly.

The population of the county in 1920 was 10,699. The western, central, and southern parts of the county are well settled, but in the northeastern part settlement is still rather sparse.

Two railroad systems furnish adequate transportation for the better-settled parts of the county.

The climate is temperate, with warm summers and cold winters. The average frost-free season is between 120 and 130 days.

Agricultural settlement began in the county during the seventies, following the construction of the first railroad in the southern part of the county. In 1925, 57.2 per cent of the county was in farms.

The present type of farming is a general and rather diversified form in which dairying is the most important of the livestock enterprises and corn and oats are the grain crops of largest acreage. A considerable part of the corn is used as fodder and silage. The chief cash crops are potatoes, sweet corn, and flax, and some tame hay and grain seeds, wheat, and buckwheat are sold. About one-half the hay raised is wild hay. Timothy, red clover, alfalfa, and some sweetclover are the tame hays grown.

The farms of the southern and western parts of the county are well improved, but those in the other parts average only fair in improvements. Only about one-fifth of the farms are operated by tenants.

The well-drained soils of the county can be grouped under two main and distinctive groups, one with dark and the other with light-colored surface soils. The dark-colored well-drained soils comprise about 15 per cent of the county's area. In this group are the Wadena and Hubbard soils. The light-colored well-drained soils comprise about 43 per cent of the area of the county. In this group are the soils of the Rockwood and Kinghurst series (well-drained soils with variable numbers of bowlders on the surface and in the soils) and of the Menahga and Aldrich series (well-drained bowlder-free soils).

Between these two main groups is an intermediate group of soils having shallow dark-colored or only slightly darkened surface soils. In this group are the excessively drained Nymore, Central, and Marquette soils and the favorably drained Thomastown soils. All these soils, except certain areas of the Marquette, are bowlder free. This group of soils comprises 6 per cent of the county's area.

Poorly drained mineral soils are grouped in the Sebeka, Granby, Newton, and Bluffton soil series.

Griffin silty clay loam occurs in stream bottoms.

The organic soils, peat and muck, and a miscellaneous group of alluvial soils, undifferentiated, comprise about 25 per cent of the area of the county. These are poorly drained and almost entirely utilized as pasture and wild-hay meadows.

The main agricultural soils of the county are those of the Menahga, Rockwood, and Wadena series. The Menahga soils are the least productive and most droughty; the Wadena are fertile, with a slight tendency to droughtiness; and the Rockwood are fertile and drought resistant but can not be worked so early in the spring as the Wadena and Menahga soils.

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[PUBLIC RESOLUTION—No. 9]

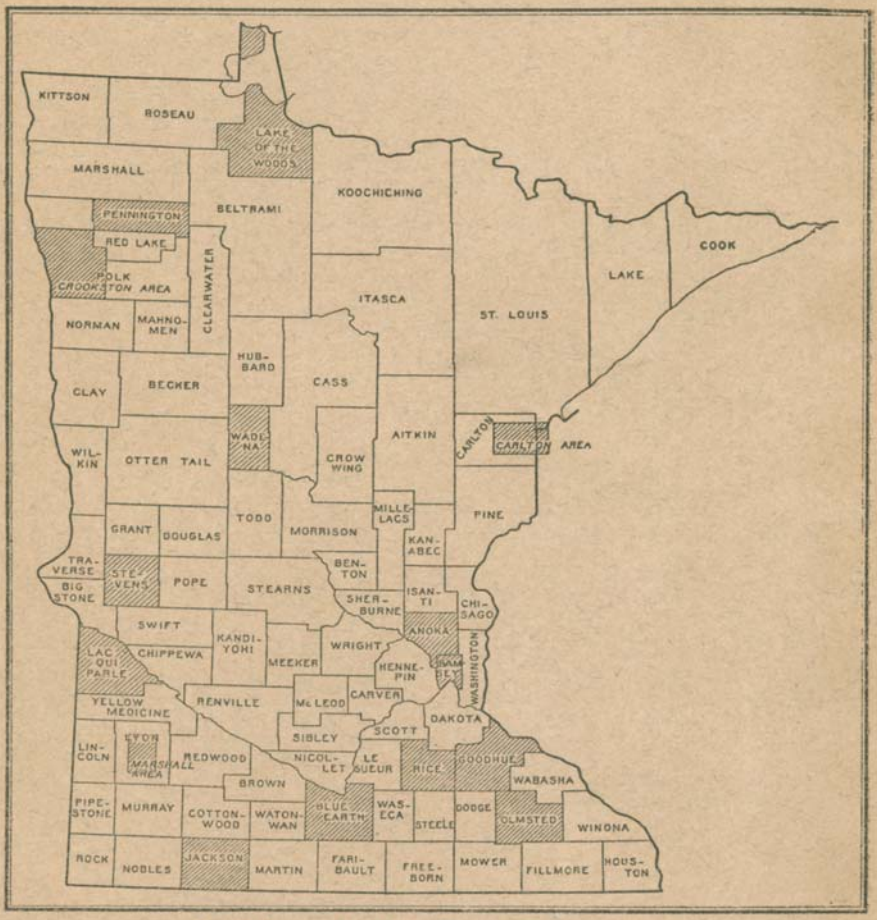
JOINT RESOLUTION Amending public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, "providing for the printing annually of the report on field operations of the Division of Soils, Department of Agriculture."

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, be amended by striking out all after the resolving clause and inserting in lieu thereof the following:

That there shall be printed ten thousand five hundred copies of the report on field operations of the Division of Soils, Department of Agriculture, of which one thousand five hundred copies shall be for the use of the Senate, three thousand copies for the use of the House of Representatives, and six thousand copies for the use of the Department of Agriculture: *Provided*, That in addition to the number of copies above provided for there shall be printed, as soon as the manuscript can be prepared, with the necessary maps and illustrations to accompany it, a report on each area surveyed, in the form of advance sheets, bound in paper covers, of which five hundred copies shall be for the use of each Senator from the State, two thousand copies for the use of each Representative for the congressional district or districts in which the survey is made, and one thousand copies for the use of the Department of Agriculture.

Approved, March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized as the Bureau of Soils, and on July 1, 1927, the Bureau of Soils became a unit of the Bureau of Chemistry and Soils.]



Areas surveyed in Minnesota, shown by shading

U. S. GOVERNMENT PRINTING OFFICE: 1930

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U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF CHEMISTRY AND SOILS
HENRY G. KNIGHT, CHIEF
A. G. McCALL, CHIEF, SOIL INVESTIGATIONS
CURTIS F. MARBUT, IN CHARGE SOIL SURVEY

SOIL MAP
WADENA COUNTY
MINNESOTA

UNIVERSITY OF MINNESOTA
AGRICULTURAL EXPERIMENT STATION
W. C. COFFEY, DIRECTOR
F. J. ALWAY, IN CHARGE SOIL SURVEY

Thomas D. Rice, Inspector, District 3.
Soils surveyed by J. Ambrose Elwell, in charge, Mark Baldwin, W. W. Strike and G. A. Swenson, U. S. Department of Agriculture, and P. R. McMiller, J. S. Hall, E. A. Fieger, S. N. Hill and J. H. Ellis, University of Minnesota.

Scale 1 inch-1 mile
1 ½ 0 1 2 3 4 Miles

LITHO EASTERN OFFSET INC., BALTO.

Field Operations
Bureau of Soils
1926